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RESEARCH ARTICLE OPEN ACCESS

# DESIGN AND DEVELOPMENT OF SELF STABILITY SYSTEM FOR THE REAL TIME MOTORCYCLES

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**ABSTRACT**

Modern motorcycles are now manufactured with more attention to how they look and how air moves around them to make them more attractive to buyers. However, this focus sometimes ignores how well the rider can stay balanced, especially when moving slowly. Keeping the bike steady in these situations can be tough. This study looks at how to improve motorcycle balance and make the bike more stable by using a gyroscope. The research includes testing how the motorcycle reacts when it starts to fall, and then designing and checking a gyroscope system based on those tests. The main goal of this paper is to check if adding stability using two gyroscopes along with a double flywheel can make motorcycles more balanced without making them less safe. This method helps both skilled riders and new riders who are learning to ride two-wheelers.



## I. INTRODUCTION

Developing countries like India, motorcycles are more popular than cars because they are cheaper to buy and use. However, motorcycles are not as safe as cars and are harder to balance when moving slowly, which makes stability a big issue, the desi gning of self-balancing two-wheeler plays a vital role for physical challenged people. Validating the prototype model using gyroscopic technique and modelling the vehicle and evaluating the experimental model, the system is based on Lagrangian mechanics and uses the idea of an upside-down pendulum, making it a method that is easy to copy and use to make motorcycles more stable [1]. This project aims to make motorcycles more stable by using gyroscopes and study of self-balancing two-wheeler with double stabilization techniques used for balancing the two wheeled motorcycle. Earlier research, including real-time fall data from the 2006 to 2016 MotoGP, found that motorcycle falls often happen because of loss of grip and sudden rocking movements [2]. Different ways to improve balance have been tried, like adding extra wheels, flywheels, and balancing weights, but gyroscopes are considered the best solution [3].

Flywheels work like gyroscopes, creating a stabilizing force called precession, which helps keep the motorcycle upright even when it's not moving, this approach was tested through computer simulations using MATLAB/Simulink and real-world prototypes [4]. The study looks at factors like how hard it is to spin something, how fast it spins, and how accurately the spinning axis is aligned to design and improve a system with two gyroscopes [5]. The system can spot signs that a driver is getting tired, which can help stop accidents caused by imbalance and tiredness [6]. Testing showed that this system can lower the chance of accidents by catching strange driving behaviour as it happens during driving [7]. The research analysis found that this system makes braking quicker and more stable, which helps stop the motorcycle smoothly and prevent skidding when stopping suddenly [8]. This paper looked at how metal and rubber materials affect how much tools used for boring can dampen vibrations. The research studied the properties of bio-composites made from Aloe vera and hemp fibres [9]

The hybrid method was found to be stronger and longer-lasting than other methods, making the joints work better. The study found that this kind of seat belt greatly reduces movement and the risk of injury compared to regular seat belts [10],[11]. The study showed that using IoT improves car performance, makes driving safer, and gives a better driving experience [12]. The results showed that this method is more efficient and produces more water than traditional systems [13]. The findings showed that this system can stop the car automatically to prevent collisions, without the driver needing to do anything [14]. The study explained how continuous monitoring can improve road safety by finding early signs of tiredness or other health issues [15]. The results showed common signs of fatigue, which showed the need for monitoring systems to help prevent accidents caused by reduced alertness [16]. The study looked at a new design for the intake manifold for automobile that run on various types of design intake [17].

The results from computer simulations showed that the stronger front structure could absorb more energy during a collision, reducing the chances of injuries to the people inside. There were also studies on engines design along with a technique on analysis process and this studies found that analysis techniques [18], [19]. The study developed an onboard driver monitoring system combined with an enhanced braking mechanism to improve driver response in unsafe conditions. The system showed potential to reduce accident risk through timely braking intervention [20]. Frontal crash tests showed that five-point seat belt systems provide better occupant restraint and reduce injury severity. The study confirmed the importance of restraint design in improving crash safety [21]. The numerical analysis found that side-mounted vortex generators improve airflow behavior and vehicle stability. The results indicated reduced aerodynamic losses using passive flow control methods [22]. Material optimization using ANSYS showed noticeable improvement in strength and durability of two-wheeler suspension components.

The study confirmed that suitable material selection enhances performance while reducing weight [23]. The investigation demonstrated that variable geometry micro-channel heat exchangers improve heat transfer in automotive air-conditioning systems. Enhanced cooling performance was achieved through optimized tube and fin design [24]. An active braking system integrated with driver condition monitoring was shown to improve braking response during critical situations. The approach enhanced preventive safety in passenger vehicles [25]. The study addressed data security challenges in e-healthcare systems and proposed methods to protect patient information. The framework ensured privacy without affecting system reliability [26]. Experimental results showed that a semi-automatic parking brake system offers reliable and low-cost safety improvement for passenger vehicles. The system performed consistently under operating conditions [27], [28]. The studies demonstrated that real-time self-stability systems using sensor-based feedback can significantly improve motorcycle balance and rider safety during dynamic operating conditions [29-31].

## II. MATERIALS AND METHODS

This method requires the use of flywheels as gyroscope on the two-wheeler so that the self-aligning properties of the gyroscope are imparted to the two wheelers on which it is installed. The different types of vehicles currently in use were identified for the study and their different specifications were noted that were required for further calculations and analysis. The purpose of the position of the center of gravity was an important part in the study. Thus, by careful approximation the position of center of gravity was determined to be at the half of the wheel base of the vehicle. For this study, the prototype was built in such a manner that it would be the exact replica of the real time model but in a smaller way i.e. it could be built in the exact same way but with changes to the dimensions. The prototype was built using specific materials, and several difficulties arose during its development, mainly concerning the position and weight of the gyroscopic flywheel. To overcome this, the gyroscope was mounted at different points on the frame and supported with beams of varying dimensions. However, the overall frame size and the wheels supporting the structure were kept unchanged and used as a constant reference for the design.

### II.1 SYSTEM DESIGN FOR FORMULA DERIVATION

Motion equations are derived by method of Lagrange. This approach is extracted from energy survival for every rigid process structure. There are three rigid body elements, i.e. vehicle body, first flywheel and second flywheel. The Lagrange equation determines first L= TV, where T is the system's actual kinetic energy and V is potential power. The kinetic and potential body and flywheel power equations are based on [14].

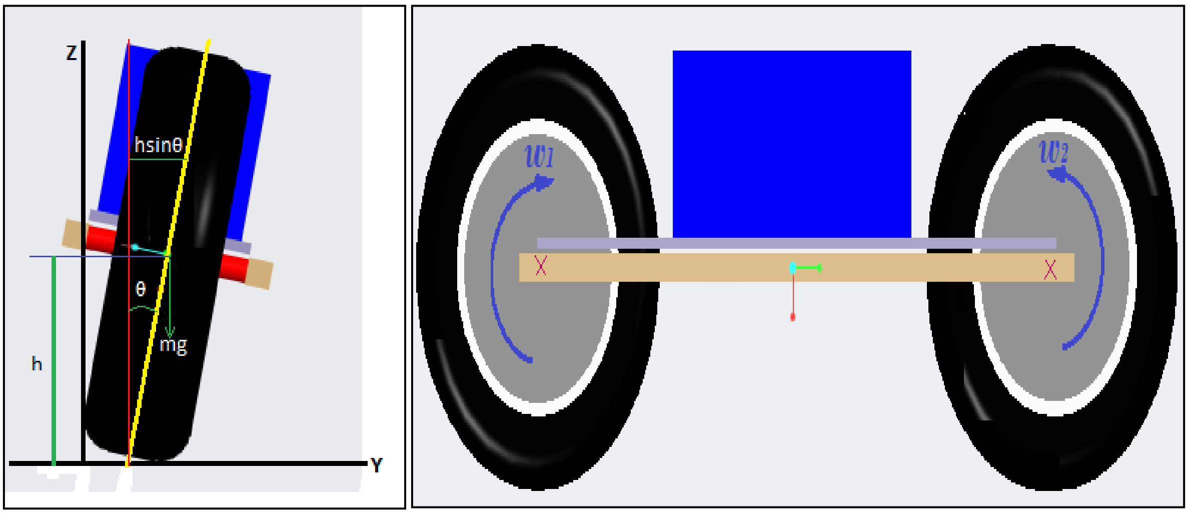


Figure 1: Free body diagram of gyro vehicle.
Source: Authors, (2026).

The coordinate of a vehicle is defined as:

$\theta$ - Tilt angle of motorcycle
$\omega_1$ - Direction of rotation of Flywheel 1
$\omega_2$ - Direction of rotation of Flywheel 2
Mass and centre of vehicle - $m_b$&$Cg_b$
Mass of 1st and 2nd flywheel - $m_{gl}$ & $m_g$
Center of mass of 1st and 2nd flywheel - $Cg_{gl}$ & $Cg_{g2}$
Moment of Inertia of motorcycle -$I_{mx}$
Moment of Inertia of 1st and 2nd of flywheel- $I_{glx}$, $I_{gly}$, $I_{glz}$ ; $I_{g2x}$, $I_{g2y}$, $I_{g2z}$
$H = m_b Cg_b^2 + m_{g1} Cg_{g1}^2 + m_{g2} Cg_{g2}^2$
$M = m_b Cg_b + m_{g1} Cg_{g1} + m_{g2} Cg_{g2}$

In order to derive the motion equation of the gyro motorcycle, the assumptions made are as follows:

- Flywheel 1 and 2 rotation speeds are same but in the opposite direction.
- The vehicle is stationary.
- No external force is applied.

The Lagrange's method was used for derive equation of motions written with that assumption as:

$$\frac{d}{dx}\left(\frac{\partial l}{\partial \theta}\right) - \frac{\partial l}{\partial \theta} = 0$$

The derivation of the Lagrange equation is made by the final coordinate deserved. The speed of the inclined angular vehicle is achieved according to the above equation.

$$\ddot{\theta} = \frac{2k_1 \sin\dot{\theta} + 2k_2 \sin\dot{\theta} - l_{g1z}\,\theta - l_{g2z}\,\dot{\theta} - \dot{M}_g \sin\theta}{l_b + H}$$

The inputs used by Matlab Simulink were initial angle variation of inclination and flywheel rotation speed by performing vehic le angle occurred at zero-degree axis.

## II.2. CONSTRUCTION OF GYRO VEHICLE

The flywheel fixed inside of wheels. Wheels were fitted to the steel frame; the mass should be dominant on the top of frame. (The centre of gravity is thus just above the wheel axis, stainless steel disc used as flywheels were fixed with the DC motor. The 12V battery was connected to the motor. The on/off switch was connected in series to the motor so that in would control the flow of the current to the DC motor only when needed. Figure 2 the model has been made in such a way that the front and rear wheels could move to take turns to change motorcycle direction (13). The accelerometer was placed in the same axis with the motors to get better readings from the motion sensors. Table 1 contains what are the data used for develop prototype model.

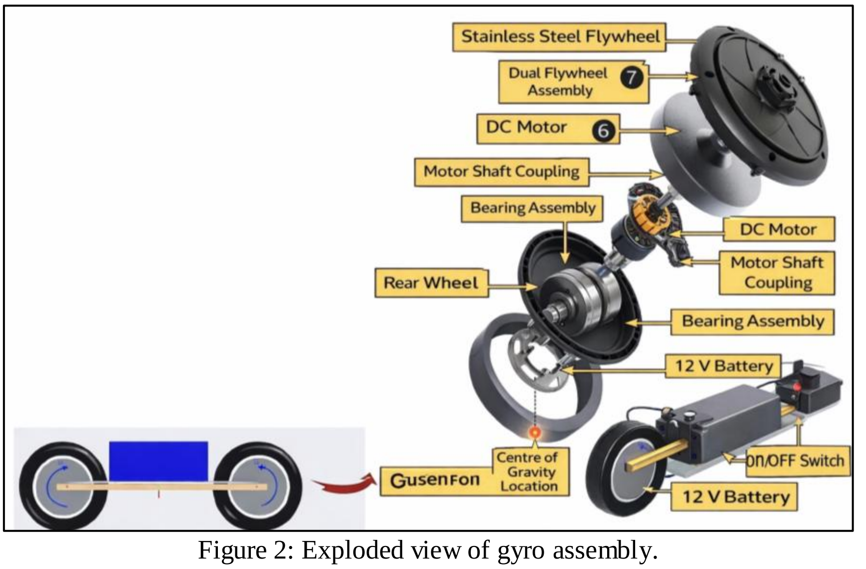


Figure 2: Exploded view of gyro assembly.
Source: Authors, (2026).

## II.3. PROTOTYPE OF GYROSCOPE ASSEMBLY.

The model was made to lie on its side. Then the motor was made to run, which spun the flywheel. As the speed increased, the whole setup gradually started to rise. The motor and frame reach the stationary position after only a few rotations and oscillations of the motor, and the pure rolling movement is created by the gyroscope on the spin axis. This rotation of the disc produces the gyroscopic effect so that when the wheels lose their stability by virtue of the active gyroscopic pair, a gyroscopically couple is produced on the other hand. This gyroscopic effect is conducted both on the front and rear wheels. The complete assembly of prototype gyro shown in Figure 3.

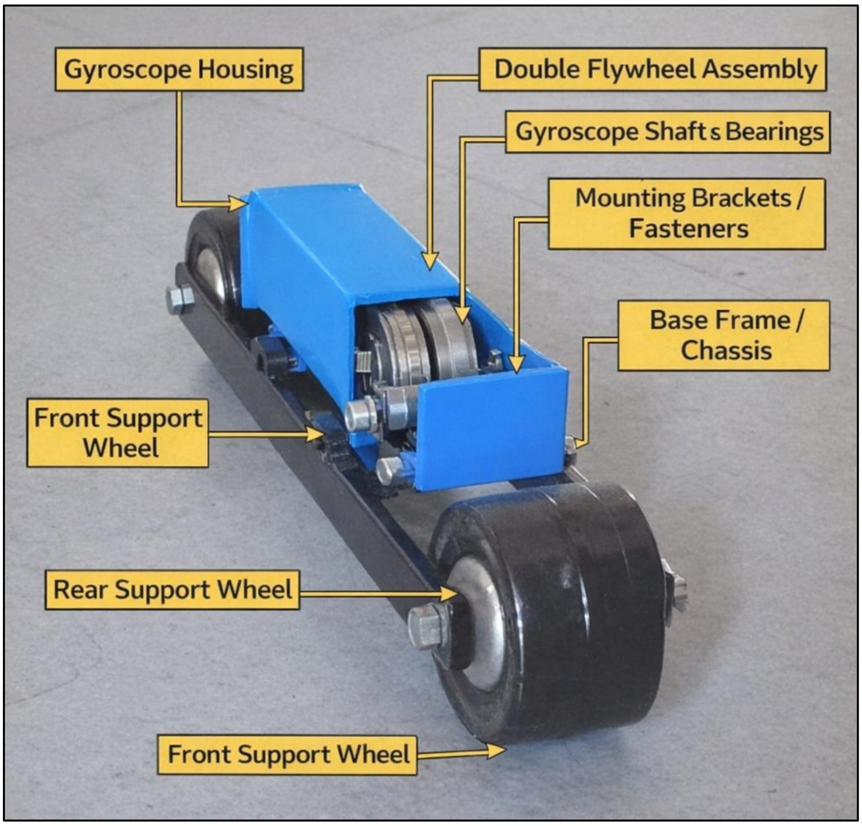


Figure 3: Prototype of gyro assembly.
Source: Authors, (2026).

## II.4. HARDWARE SYSTEM DESIGN CONSTRUCTION

Stabilization of the Control Moment Gyroscope (CMG) uses a high-speed flywheel's reactive precession torque around an axis that acts to balance the vehicle. This paper proposes a development of proportional integral derivative (PID) controller for first order sliding mode to control the CMG and stabilize a bicycle at zero-forward speed. In this article, a motorcycle flywheel with one DOF is used to inducing the torque to overcome the torque by the gravity of its balanced vertical position when it is applied on the two wheels. A simultaneous, amplified reactive torque is produced around an orthogonal axis on both the axis of the flywheel and the spin axis by use a torque on a rotating flywheel. This controlled reactive torque can be designed to balance the axis of an unstable two-wheeler. Motorcycle balancing means that the vehicle attempts, by moving left or right for an induced lean angle, to return vertically or not to fall over. For this function we have to do two things: firstly, we must calculate the angle of inclination (roll) of the vehicle, and then we must control the speed of the engines to achieve this angle 0. Wink Measurement:

The accelerometer can measure the force of the gravity and the angle of the two wheels can be obtained.from the figure 4 illustrates the schematic diagram of gyroscope vehicle and it had labelled clearely.The gyroscope calculates the angular velocity and, if this calculation is combined, the magnetic angle of the twowheel moved i s not optimal and the integration has an integration variance.The combination of these sensors, called sensor fusion, will overcome these issues, and there are a great number of ways of combining them. It was named MPU6050. MPU6050 had the ability to use the detectors to collect accurate data directly from the chip without having to solder the sensors manually. Two engines spin two fly wheels separately so that we can alter the engine inputs in the correct location of the two wheels. We also use PID to provide a smoother calming reaction. To order to maintain the equilibrium position, the accelerometer tests the chase speed and the gyroscope. The ties we used during this a nalysis are shown in the figure below. In order to better read from the motion sensors, the accelerometer was positioned in the same dire ction with the enginesIt was also important to check the reliability of the proposed controller model. A basic PID controller was also added to the system to check this.

The PID controller have been designed as-

$$u = K_P e(t) + K_D\, d/dt e(t) + K_I \int e(\tau) d\,\tau$$

Where KP, $K_D$, and $K_I$ are gains in proportion, derivative, and integrator, and $e_{(t)}$ is the difference between the current angle of tilt and the ideal angle ($\theta = 0$)(20).

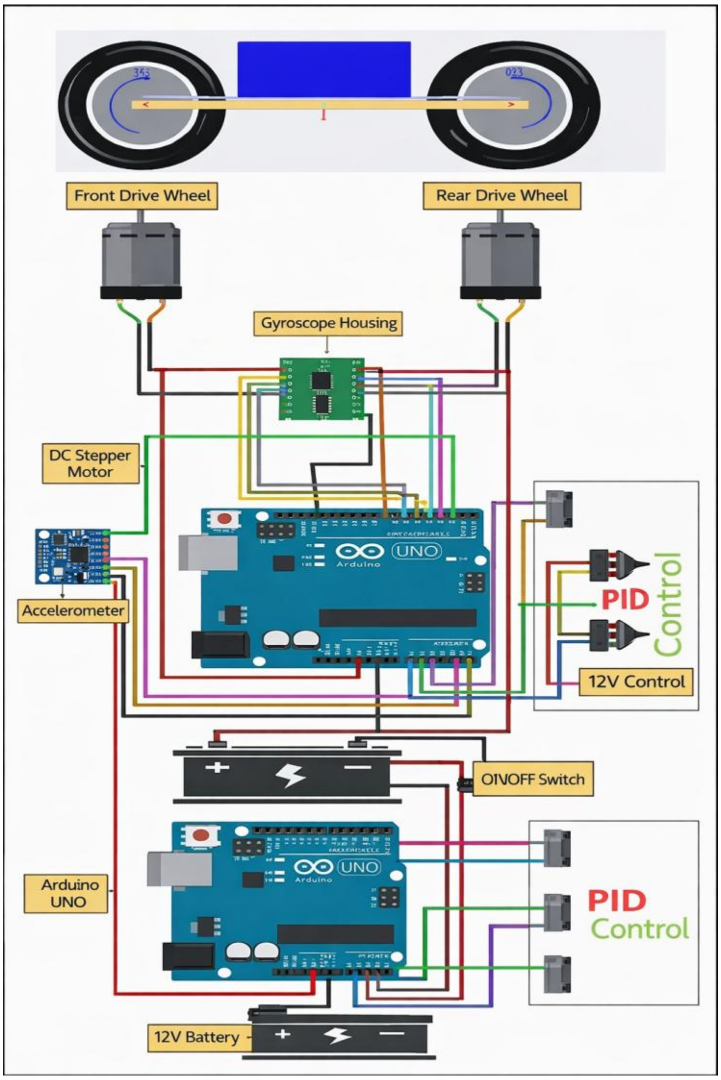


Figure 4: Schematic diagram of gyro vehicle.
Source: Authors, (2026).

## III. RESULT AND DISCUSSION

Gyroscope is based on the principle that the angular momentum varies in torque direction. The simple principle behind this study is to give a counter force to the vehicle when it is under a fall.

Couple incurred during fall of a two-wheeler

$$C= W*h \tag{1}$$

Where,

W = Weight of two-wheeler in kg.
h = height of center of gravity from the ground m.
The course of the fall when traced took place in a quarter of the circle. The time taken was iterated to 1.5 seconds.
Hence, Basic formula for the minimum angular momentum required to stabilize the vehicle.

$$W*h^2\pi/ (2*1.5) \tag{2}$$

But angular momentum of a gyroscope is

$$L = I*\omega \tag{3}$$

$I = M*r^2$
$\omega= N*2\pi/60$
Substituting I and ω in (3)
We get,
$L= M*r^2*N*2\pi/60$

Where,

L= angular momentum of gyroscope $kgm^2s^{-1}$.
I = moment of inertia of the disc kgm.
ω = angular velocity of gyroscope m/s.
M= Mass of flywheel kg.

r = radius of the flywheel m.
Torque $\tau$= Frsin$\theta$
Force F=mg

Thus, by equating (2) and (3), we can determine the required angular momentum to be induced by the gyroscope. We have designed and made a self-balancing system for motorcycle. The model works on the principle of spinning wheel fixed inside of wheel.

Table 1: Parameters to design.

| | |
|---|---|
| Front wheel dia - cm | 20 |
| Rear wheel dia (r)- cm | 20 |
| Overall mass- kg | 20 |
| Wheel base- cm | 50 |
| CG Point(h)- cm | 30 |
| Mass of Disc(m)- kg | 0.25 |
| Radius of Disc(r)- cm | 5 |
| Motor speed (N) RPM | 500 |

Source: Authors, (2026).

Angular momentum of a gyroscope

$L= I \omega$

Moment of inertia of the disc

$I=mr^2$.
$I=0.25*0.05^2$
$I=0.000625$ kg $m^2$.
$\omega = N*2\pi/60$
$\omega =500*2\pi /60$
$\omega =52.3s^{-1}$
L=0. 000625*52.3
L=0.0326 $kgm^2$ $s^{-1}$

Thus, the prototype can balance the vehicle up to the angular momentum of 0.0326$kgm^2$ $s^{-1}$

Table 2: Variation of Moment of inertia and Angular momentum of a gyroscope with respect to mass.

| **S.No** | **Mass-Kg** | **Moment of inertia- kg $m^2$** | **Angular momentum of a gyroscope- $kgm^2$ $s^{-1}$** |
|---|---|---|---|
| 1 | 0.25 | 0.000625 | 0.0326 |
| 2 | 0.26 | 0.00065 | 0.0339 |
| 3 | 0.27 | 0.000675 | 0.0353 |
| 4 | 0.28 | 0.0007 | 0.0366 |
| 5 | 0.29 | 0.000725 | 0.0379 |
| 6 | 0.30 | 0.00075 | 0.0392 |

Source: Authors, (2026).

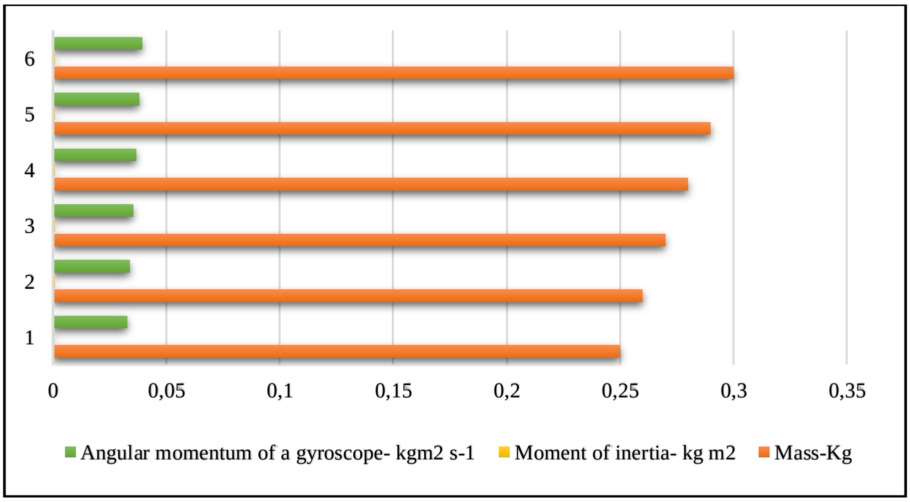


Figure 5: Mass vs Moment of inertia and Mass vs Angular momentum.
Source: Authors, (2026).

Figure 5gives us a clear idea that the moment of inertia created by the gyroscope will increase if we try to increase the mass of the flywheel can say that the time of inertia (MI) varies along with different masses of the fly wheel, relation between the fly wheel mass and the gyroscope angular momentum. Here, we can see that the angular momentum also increases in the response to the variable the fly wheel weight, which means that the range is a different factor for the gyroscope to get variable angular momentum values.

Table 3: Changes of flywheel speed with respect to tilt Angle at constant mass.

| S. No | Tilt angle- θ | Flywheel Rotation -RPM |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 5 | 190 |
| 3 | 10 | 250 |
| 4 | 15 | 280 |
| 5 | 20 | 330 |
| 6 | 25 | 410 |
| 7 | 30 | 500 |

Source: Authors, (2026).

Figure 6 shows the results by changing the angle of inclination to get the corresponding speed values to change the tilt angle values. If the tilting angle increases, the torque value of the gyroscope is modified. In this analysis, the flywheel inertia is constant for each change of the input vehicle's inclination angle; so that the flywheel rotation speed required stabilizing the vehicle increases with the vehicle angle inclination. The greater the vehicle's angle, the greater the vehicle's torque.

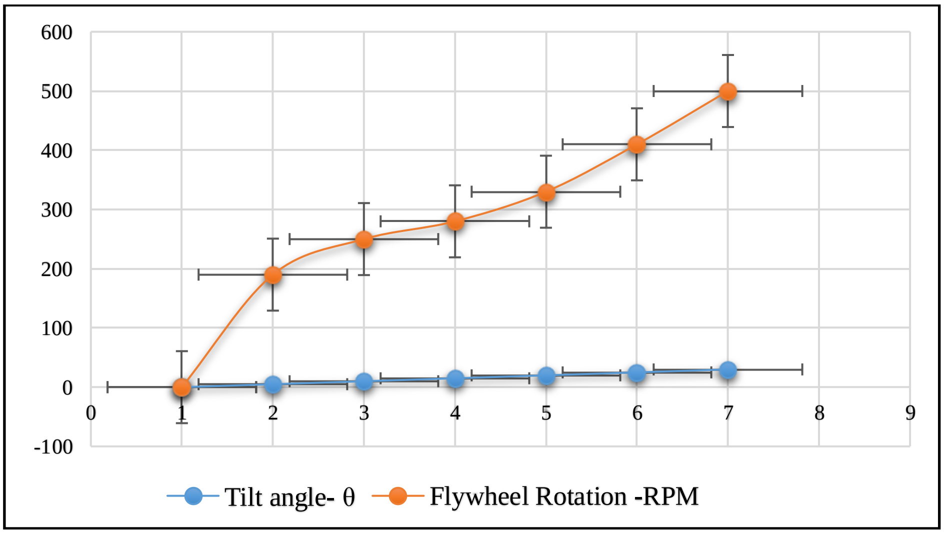


Figure 6: Tilt angle vs Flywheel rotation.
Source: Authors, (2026).

The results obtained in the form of the graph containing vehicular angle stabilization with a vehicle flywheel rotation speed were extracted from the theory test using Matlab Simulink. The vehicle angle changes test results are shown in TABLES 3. As for one of the theoretical testing charts shown in Figure 7. The vehicle incline angle is used as input parameter (θ) at 05, 10, 15, 20, 25, and 30. The result is 190 rpm, up to a 500-rpm flywheel rotation to stabilize the 00-30 incline angle from Simlink Matlab. The couple that is induced during fall was calculated based on the collected data for each vehicle. For each vehicle, the required angular momentum of the gyroscope was calculated and recorded. A scaled prototype was developed to demonstrate the stability of a two-wheeler using a flywheel as a gyroscope, and the gyroscopic force generated by the flywheel was calculated. In this model, only the forces acting along the lateral axis were taken into account, while factors such as driving force, vehicle velocity, braking force, and air resistance along other axes were excluded from consideration.

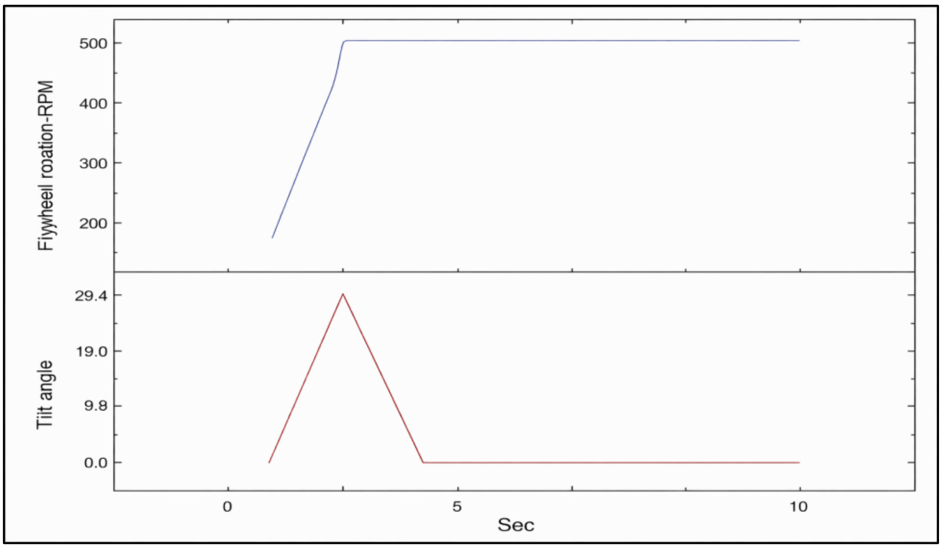


Figure 7: Stabilization graph at $30^0$ - 500RPM.
Source: Authors, (2026).

For the prototype, the gyroscopic force of the flywheel was calculated to be 0.37 kg·m²/s at a rotational speed of 500 rpm, based on the given specifications. The motor speed was maintained at 500 rpm, while the flywheel mass was varied by adding or removing weight. The angular momentum generated by the system remained within the counteracting force of the flywheel, allowing the vehicle to maintain balance without external support. With these positive results, the study provides a basis for extending the concept to real vehicle applications in future work. The two wheeled model was stabilized by the usage of the gyroscopic force (i.e. angular moment) induced by the flywheel. Different types of motorcycle were selected based on this study were categorized into scooter, standard and sports shown table 2.

**Case 1**

W= 103kg
h= 0.619m
L= $W*h^2/(2*1.5)$
L= 103*0.6192/(2*1.5)
L= 13.155 $kgm^2$s-1.
Thus,
13.155= M*r2*N*2π/60
13.155= M*N*0.07622*2π/60
M*N=21,634
M= 5kg
**N= 4326rpm**

Thus, the required mass 5kg and the required speed 4326rpm the gyroscope that is required for the self-balancing in standard model motorcycle was found theoretically.

**Case 2**

W= 119kg
h= 0.652m
L= W*h2/(2*1.5)
L= 119*0.6522/(2*1.5)
L= 16.826 kgm2s-1.
**Thus,**
16.826= M*r2*N*2π/60
16.826= M*N*0.07622*2π/60
M*N=13,817
M= 5kg
**N= 2763rpm**

Thus, the required mass 5kg and the required speed 2763rpm the gyroscope that is required for the self-balancing in standard model motorcycle was found theoretically.

**Case 3**

W= 135kg
h= 0.6725m
L= $W*h^2/(2*1.5)$
L= $135*0.6725^2/ (2*1.5)$
L= 20.351 kgm2s-1.
**Thus,**
20.351= M*r2*N*2π/60
20.351= M*N*0.07622*2π/60
M*N=16,676
M= 5kg
**N= 3335rpm.**

Thus, the required mass 5kg and the required speed 3335rpm the gyroscope that is required for the self-balancing in sports model motorcycle was found theoretically.

Table 4: Data for three types of motorcycle.

| Case/Description | Case -1 Scooter | Case -2 Standard | Case -3 Sports |
|---|---|---|---|
| Wheel Dia (f)- m | 0.3048 | 0.4318 | 0.4318 |
| Wheel Dia (r) -m | 0.3048 | 0.4318 | 0.4318 |
| Overall Mass- kg | 103 | 119 | 135 |
| Wheel base- m | 1.238 | 1.305 | 1.345 |
| CG Point -m | 0.619 | 0.6525 | 0.6725 |
| Mass of Disc- kg | 5 | 5 | 5 |
| Radius of Disc- m | 0.0762 | 0.10795 | 0.10795 |
| Speed Approx- RPM | 4326 | 2763 | 3335 |

Source: Authors, (2026).

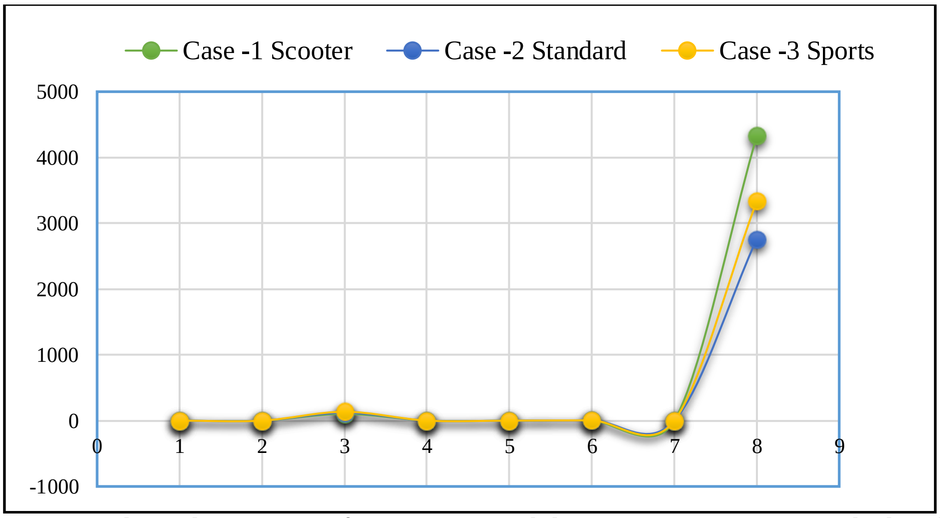


Figure 8: Comparative rotational speed requirement for gyroscopic stabilization across scooter, standard, and sports motorcycles.
Source: Authors, (2026).

From Figure 8. The scooter configuration requires the highest disc rotational speed, indicating a greater gyroscopic input needed to compensate for its lower mass and shorter wheelbase.The standard motorcycle shows the lowest required speed, reflecting a more balanced contribution from mass distribution and wheelbase length. The sports motorcycle exhibits an intermediate trend, where higher mass improves stability but still demands elevated disc speed due to its geometry and dynamic characteristics.

## V. CONCLUSION

The proposed method successfully enabled the vehicle to achieve self-stability. The model operates on the principle of a spinning wheel mounted within another wheel. This study was undertaken to address the challenge of balancing motorcycles and to enhance their stability. The concept involves using a dual-gyroscope system with double flywheels, followed by testing, designing, and analysing the gyroscope based on the results obtained. A prototype of the gyroscopic stability system for motorcycles was developed and validated, with corresponding calculations performed and operational limits defined. This work benefits not only experienced riders but also individuals who are in the process of learning to ride two-wheelers.

## VI. AUTHOR’S CONTRIBUTION

**Conceptualization:** C. Dineshkumar, N S Shafeer Ahmed, Mohamed Jaheen.
**Methodology:** C. Dineshkumar, N S Shafeer Ahmed.
**Investigation:** Mohammed Rizwan, Mohammed Harris.
**Discussion of results:** C. Dineshkumar, N S Shafeer Ahmed.
**Writing - Original Draft:** Mohamed Jaheen, Mohammed Rizwan.
**Writing - Review and Editing:** S Syed Burhan, K Samsudeen.
**Resources:** C. Dineshkumar, N S Shafeer Ahmed.
**Supervision:** C. Dineshkumar, N S Shafeer Ahmed,
**Approval of the final text:** C. Dineshkumar, S Syed Burhan, K Samsudeen.

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