Design of Gyroscopes for Stabilizing Two-Wheeler

Vishwajeet Chaudhari[1], Jitesh Kotian[2], Prasad Jagdale[3], Shubham Misal[4]

[1]Vishwajeet Chaudhari, Department of Automobile Engineering, Pillai HOC college of Engineering & Technology, Maharashtra, India.
[2]Jitesh Kotian, Department of Mechanical Engineering, MGM's College of Engineering & Technology, Maharashtra, India.
[3]Prasad Jagdale, Department of Mechanical Engineering, Pillai HOC college of Engineering & Technology, Maharashtra, India.
[4]Shubham Misal, Department of Mechanical Engineering, Pillai HOC college of Engineering & Technology, Maharashtra, India

---

ABSTRACT: *Stabilizing plays a major role to help in avoiding the majority of an accident in two-wheelers. Gyroscope thus helps to develop the counteracting forces against the tilting force. The safety aspects of the vehicle are increased by incorporating a gyroscope mechanism in the two-wheeler. The torque generated by the gyroscope must be equal to the imbalance torque acting on the vehicle for the dynamic stabilization of the vehicle. The main principle is about generating the counteracting torque to help stabilize the tilting vehicle. The design for the gyroscope was thus finalized, and then designing, modelling and fabrication were done to successfully experiment. The stabilizing effect is thus generated by the rotating gyroscope mounted on the vehicle.*

Key Words: Gyroscope, Self Stabilizing Two-Wheeler, Self Balanced Bike, Safety, Balancing.

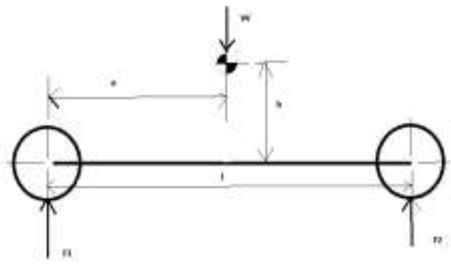
INTRODUCTION:

Our project focuses on the concept of a self-balancing two-wheeler car. We aimed to design a two-wheel car which will be self-balanced by using the gyroscopes in it. The project also details about the model making for testing of balancing a two wheeler which can be designed like a car to increase the safety features and comfort conditions similar to two wheeler. Gyroscope is nothing but the rotating disc which will counteract the unbalancing forces acting on the vehicle. In this project, we have used two discs which create the gyroscopic effect generating counter reacting couple when the vehicle unbalances on either side. The drive sources to the gyro are directly given by the motor. The gyroscopes are required only when the speed of the vehicle is standing still, for the rest of the period when the vehicle is in motion it balances itself. The applications of the gyroscopes are vast, thus incorporating this in two-wheelers will make it safer. Weight and speed are the two main factor which guides the actual performance and balancing of the gyroscope. For designing the gyroscopes various factors are taken into account and based on that the various equations are derived. The speed calculations for the gyroscope is required to determine the rpm of the disc as it varies depending on the weight on the vehicle. After designing the gyroscope the test has been done to study the stability of the system and for the simulation results. Finally, we discussed a scaled model designing and testing.

Awadhesh Kumar Yadav et al [1], Proposed airbags in two wheeler as an enhanced safety feature and reduce the accident injury by more than 50%. These systems included airbags to be installed on the front handle of the airbag to act as a safety cushion for driver's head during any collision. Also, two airbags were provided on either side of the bike which will be activated upon a detection of less than 30⍰angle between bike and road. Dr. -Ing. Achim Kuschefski et al [2], Proposed the idea about assistance system during driving or riding. ARAS is used as a term to describe about the collection of safety systems which can be incorporated in bikes to increase the safety of the rider and reduce the tendency of accidents. The various strains faced by the rider both physical and fatigue by the riders as compared to automobile drivers are clearly stated. Hemashree Kakar [3], Proposed the calculations for the designing of gyroscope and its related parts for the fully functional and it's stabilizing operation. The balancing is achieved by the counteractive gyroscopic couple produced against the active reactive couple. The conclusion drawn stated about the relation between the speed of hub motor rpm and counterforce produced. Also the relation between tilt angle and stability was mentioned based on the experiment results. Pallav Gogoi et al

[4], Proposed the designing, modelling, fabrication of a two wheeler model to state the working of principle of gyroscopic couple for stabilizing purpose. The stability of the model is verified under various load by varying the gyroscope rpm. N. Tamaldin et al [5], Studied previous researches and found one suitable and efficient method to design the self stabilizing bicycle with the help of control moment gyroscope. Guoping You et al [6], Designed a two wheel balanced car with the help of chip controller and gyroscope accelerometer as a sensor. The chip used is STM32F103C8T6 and the gyroscope accelerometer MPU6050 is used. The algorithm is written to balance the bike using PID and for the drive system the motor is used which is TB6612. kazusuke meanaka et al [7], A new structure is introduced in which MEMS gyroscope is used with 2 gimbals. The gimbals are arranged in such a way that they are placed perpendicular to each other with the help of torsion bar. It has the ability to work adequately in the atmospheric pressure. This system is also uses semi digital circuit system. Yao, Jianfei et al [8], shear impact and gyroscopic impact is actuated to watch the direct and nonlinear powerful conduct of two-rotor three-bearing framework. Rotational speed, eccentric condition, and the stiffness on the dynamic behavior is discribed rigrously in the journal. Rotordynamic analysis includes evaluation of rotor speed and unbalance response. The results of the research express that these observations have the great effects on the dynamic behavior of the system. Dynamic response is more complex for flexible coupling and two mass eccentricities than that of system with rigid coupling and one mass eccentricity. Hao Dong et al [9], formulated that the wheel assembly of the locomotive is a rotor which itself has gyroscopic effect. Metelitsyn's inequality theorem for stability had some advantages to resolve the problem as this method is sufficient. As per the shakiness measure, gyroscopic contributory proportion is determined to concentrate how the job the gyroscopic impact plays in solidness. Besides, the impact of gyroscopic grid or gyroscopic terms pitch rotor idleness on the solidness coefficient is explored. The gyroscopic impact gets critical, and the security increments with expanding latency. The test for the influence of gyroscopic effect on stability needs to bemfurther studied. Ryspek Usubamatov [10], gyroscopic effect is highly sophisticated than it is presented in mathematical solutions. The results presented by any analytical model is not similar to real time forces acting on a gyroscope. Inertia forces are induced due to rotating masses is practically tested by the one side support experiment. Author had also revealed that the upward motion acting on that gyroscope in that experiment is falsely called as antigravity force. Accordingly, the analytical calculations included in the journal describes that the gyroscope does not possess any anti gravity effect. Eduarda Delgado et al [11], analysed that balancing a rotor without taking any trial runs is not possible if mode shapes are not known. Depending on the ranges of mode shapes balance is obtained. Trials are also important for negotiating the unbalanced masses. The author has also experienced difficulty related to angular positioning of vibrational actuator which determine the magnitude of unbalance forces.

1. CALCULATIONS OF C.G.



F1= 33.3 kg

F2= 49.8 kg

W= 83 kg

Considering the vehicle is on a perfect horizontal plane

Weighing the vehicle, value is approx 83kg

Considering 60-40 ratio of weight distribution on front and rear wheel as F1 and F2

- Taking MOMENT ABOUT 'A'.

F2□ -Wa□ =0

49.8□345 -83a□=0

a=709.77mm

now, considering the vehicle is place on a stepped ground making an angle of 30 with the ground taking θ as 30 degrees

- Taking moment about A

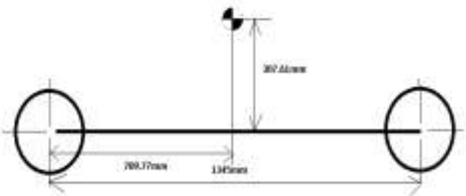
F4×lcosθ-W⍰=0

F4⍰345⍰bs30 -83⍰14.67=0

F4= 32.84kg

a= ((W⍰ -F4×l)cosθ)/(180×sinθ)

=307.61mm



The overall height of CG from ground is summation of ‘h’ and ‘ground clearence’

The value for H=307.61+250 =557.61mm

1. **Calculations of generated couple to overcome the force applied on the vehicle**

The vehicle is designed for a maximum tilt angle of 15-30 degree measured from vertical axis of the vehicle

Calculation of presision speed and gyroscopic torque

F= μ m g

= 19.82N

Dimensions of the disc as 7.5” diameter with 3mm thickness

Speed of rotation is maximum upto 4000 rpm

The moment of inertia of rotating disc is given by

Ixx =Iyy= I= mr^2/4

= 3.5⍰.1905= 0.16668kgm^2

To find the angular velocity of the disc, let ω be the angular velocity-

ω =(2×π×N)/60 = 628.31 rad/sec

calculating Torque i.e. T

T = mgHsinθ

= 83⍰.81⍰57.61⍰n30= 227.01 N.m

gyroscopic couple = reactive gyroscopic torque

I×ω×ωp = m×g×H×sinθ

Calculating highest precision speed

ωp= m×g×H×sinθ/ I×ω

=83⍰.81⍰57.61⍰n30/ 0.16668⍰28.31⍰.81

= 220.96 rad/sec

Gyroscopic Couple

C=I×ω×ωp=0.16668×9.81×628.31×220.96

=227⍰0^3 Nm^2/sec^2

COMPONENTS ASPECT:

Bearing: Bearing is selected based upon the thrust load and dimensions of the frame and gimbal rod. It is used as end support for the gimbal axis mounted over frame.

Table no. 1

Model Number	6000 Series
Type	Deep Groove Ball Bearing
Bore size	10 mm
Outside diameter	26 mm
No of Row	Single Row
Material	Stainless Steel

WIRES: It is specially designed for high current flow with thick insulation to avoid burning and heating up. The selection of the wire is done precautionary as it has to deal with the heavy current, high temperature, etc. The selection of suitable wire is done by considering the no. of factors like the rated voltage, current carrying capacity, derating factor, voltage drop, bending radius.

Table no. 2

Size	12.00 Sq mm
Length	4 m
Current Rating	15 Amp
Resistance Per Km at 20^{o} C	13.3 ohms
Conductor Material	Copper
Insulating Material	PVC Insulated
Colour	Black

GYROSCOPE: It is the key component of our system. The self-balancing of the bike depends on this gyroscope discs. The weight and the other specifications of the disc are selected concerning the vehicle weight and speed and also rpm of the discs. As per requirements, two discs have been used. The free movement of these dics in the spin axis is important to generate the reactive stabilizing couple.

Table no. 3

Material	Mild Steel
Diameter	19.5 Cm
Rpm	3000-5000
Weight	3.5 each disk

Tires: Tires are the main supporting components of the bike which is used to transmit the drive and provide motion to the vehicle. While selecting the proper tire, the kerb weight of the vehicle is considered along the CG of the mass. The specification of the tire is mentioned.

Table no. 4

Size	49�11�49
Inflation Pressure	40 For Front & 50 For Rear
Inflated dimension	112 & 416
Ply rating	6
Wheel position	Front & Rear

FRAME: Galvanised Iron bars are used for the frame as it has many advantages necessity for the project like being light in weight, it is readily available, easy to weld and bolt joints, sustain vibration etc. As it reduces the overall weight of the vehicle, it increases the gyroscopic stability on the bike.

Table no. 5

Material	Galvanised Iron
Dimensions	2.5�2.5 Cm
Sections	Rectangular

BILL OF MATERIAL:

Table no. 6

Sr no	Parts Name	Quantity	Material
1	Frame	1	Galvanised Iron
2	Tyres	2	-
3	Gyroscope	2	Iron(Fe)
4	Gimble	2	Mild Steel
5	Bearing Clamp	4	Stainless Steel
6	Wires	4	Copper
7	Batteries	2	-
8	Motors	2	-
9	Bearings	4	Stainless Steel

MANUFACTURING:

The structural section of the chassis was considered to be designed as per the lightweight model to assist in the easy balancing of the system. The base length was maintained approx of a regular two-wheeler for maintaining its original outlook. The ground clearance was calculated to accommodate the free movement of the gyroscope spin axis above the road surface. The chassis structure was made with the GI box hollow section. Front end and the back end of the frame was made hexagonal to reduce area for the incoming drag and help in equal flow of air around the vehicle.

For the attachment of wheels, a fork was attached at the front end connected with the body of the vehicle. The front sides were joined by a horizontal bar over which the steering support was mounted. The steering used was similar to a four-wheeler steering considering ergonomic aspects. The steering and the front wheel was altogether made a single structure to reduce the complexity in design and manufacturing. For the rear wheel, it was mounted over the dead axle. The ends of the axle were connected to the rear side frame of the vehicle. Small-sized tires were used to reduce the ground clearance to keep the CG of the vehicle lower. The mounting of the tires and its attachment were made rigid to accommodate for the starting vibrations of the rotating gyroscope.

For the seating arrangement, a horizontal section is welded to the side frames of the vehicle. A soft cushion as a seat was provided to absorb the vibration and also increase the comfort of the rider. The structural design was made in accordance keeping in mind the frame of a regular two-wheeler.

The gyroscope assembly was mounted over the chassis on its side structure. For the easy removal and installation, bearings were provided at the end, locked in its position with the locking clamps and held intact with the help of bolt and nut. The weight of the gyroscope was thus distributed through the gimbal over the frame uniformly.

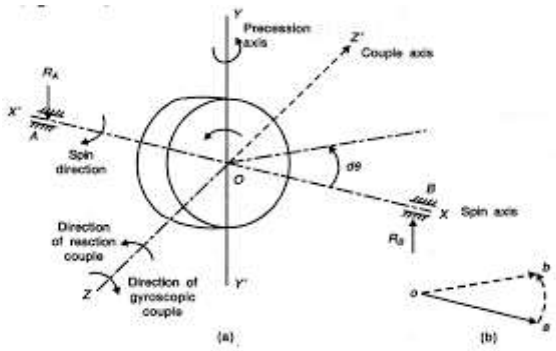
For the gyroscope structure, a hut section was made to attach the motor with the gyroscope discs. The shaft of the motor was inserted through the hut section in the centre of it and locked with a pin to restrict the sliding movement of the shaft through the hole. The hut section was bolted to the gyroscope disc to transfer the rotation movement of the motor to disc. The motor was placed over the gimbal axis. Gimbal axis structure was made using the rod, one end of which was attached to the frame and the other end was connected to the plate over which the motor was placed. Bolting and welding joints were used to join the plate along with the gimbal axis bar.

WORKING:

To understand the working of stabilizing two-wheeler it is important to study the working of a gyroscope. All rotating masses has an internal force in some case it is centrifugal and in some case it is centripetal. When the axis of rotation is precessed or misaligned from its original axis, a reactive force is generated which is equal in magnitude which tends the mass to align with its original axis of rotation. Imagine a circular mass in 3-dimensional space rotating in the YZ plane and X as the rotating axis. When this axis of rotation is misaligned in another perpendicular say ZX plane, a couple is induced on the rotating mass in the third plane (XY plane). In the case of two-wheelers, such an induced couple can be used as a stabilizing force for an unstable vehicle.

Active gyroscopic couple defines an exact change in angular momentum and this is should be applied in the spin axis of the gyroscope to precess tilt in the horizontal plane. When the axis of spin is misaligned by any outside disturbing force. Depending on the amount of tilt in the precession plane, a reactive force is produced in the third plane which is equal in magnitude but opposite in direction. This reactive force is also known as a gyroscopic couple that stabilizes the vehicle.

The motor which is directly coupled to disc when start rotating, depending on the mass and speed of the disc a reactive couple is generated which tends to align the precess axis, causing the disturbing force to neutralize. The C.G. lies above the gimbal axle. So, the motor and gyroscope try to attain the position such that the C.G. will move downwards. But the motor and gimbal area is positioned within the frame having bearing reactions at the end.



CONCLUSION:

The balancing of the designed two-wheeler model was done successfully using the gyroscope to counterbalance the tilting forces acting. Different weight was placed on the vehicle and the balancing tendency was checked by varying the speed of the gyroscope. Based on the experimentation of the project, the following conclusions were drawn:

- The tilting force of the rotating wheel experienced by the vehicle depends mostly on three factors, they are RPM of the wheel, the weight of the wheel and the angle of tilt.
- Increase in the RPM of the gyroscope, increase the amount of counterforce generated.
- The tilt direction of the rotating wheel decides the force direction of spinning.
- Balancing is achieved by the weight attached at gravity.
- Increasing the tilt angle of the vehicle needs an increase in force required to stabilize the vehicle.

The stabilizing support is only needed when the vehicle stands still. When the vehicle gains speed and is moving on the road, no stabilizing is needed as the vehicle stabilizes by itself.

REFRENCES:

1. Awadhesh Kumar Yadav, Anand Singh, Vishwajeet Singh, Mishra Shubham, Pragya Tiwari. Integrated Airbag System for Two-Wheelers. International Journal for Research in Applied Science and Engineering Technology. 2017;5(X):256-262.
2. Dr.-Ing. Achim Kuschefski, Dipl.-pad. Matthias Haasper. Advance Rider Assistance Systems for Powered Two-Wheelers (ARAS-PTW). 22nd International Technical Conference on the Enhanced Safety of Vehicles (ESV). 2015: 11-0123.
3. Hemashree Kakar. Design Calculations of a Two Wheeler Self Balances Vehicle. International Reasearch Journel of Engineering and Technology (IRJET). 2018; 05(07): 2066-2075.
4. Pallav Gogoi, Manish Nath, Bumi Trueman Doley, Abhijit Boruah, Hirok Jan Barman. Design and Fabrication of Self Balancing Two Wheeler Vehicle using Gyroscope. International Journal of Engineering & Technology (IJET). 2017; 9(3): 2051-2058.
5. N. Tamaldin, H.I.M. Yusof, M.F.B. Abdollah, G. Omar, M.I.F. Rosley. Design self-balancing bicycle. Proceedings of Mechanical Engineering Research Day 2017, May 2017, pp. 160-161.
6. Guoping You, Wanghui Zeng. Design of Two-Wheel Balance Car Based on STM32. 9th International Conference on Information Technology in Medicine and Education. 2017; 775-779.
7. Maenaka, Kazusuke & Ioku, Sunao & Sawai, Nobuhiro & Fujita, Takayuki & Takayama, Yoichiro. (2005). Design, fabrication and operation of MEMS gimbal gyroscope. Sensors and Actuators A-physical - SENSOR ACTUATOR A-PHYS. 121. 6-15. 10.1016/j.sna.2005.02.012.
8. Yao, Jianfei & Gao, Jinji & Zhang, Ya & Wang, Weimin. (2015). The Dynamic Analysis of Two-Rotor Three-Bearing System. International Journal of Rotating Machinery. 2015. 10.1155/2015/342636.
9. Dong, Hao & Zeng, Jing & Wu, Liang & Huanyun, Dai. (2014). Analysis of the Gyroscopic Stability of the Wheelset. Shock and Vibration. 2014. 1-7. 10.1155/2014/151625.
10. Usubamatov, Ryspek. (2019). Physics of Gyroscope's "Antigravity Effect". Advances in Mathematical Physics. 2019. 1-7. 10.1155/2019/4197863.
11. Preciado, Eduardo & H, Bannister. (2002). Balancing of an Experimental Rotor without Trial Runs. International Journal of Rotating Machinery. 8. 10.1080/10236210211861.