



Special Issue of First International Conference on Engineering, Science, and Technology (ICEST 2021)

Gyroscopic hybrid bicycle

Akash C B¹, Devaprasedh², Jills Babu³, Mohammed Ryan⁴, Mr. G Thilak⁵

^{1,2,3,4}Student IV Year B.E Mechatronics Engineering, Hindusthan College of Engineering and Technology.

⁵Professor, B.E Mechatronics Engineering, Hindusthan college of Engineering and Technology,

Coimbatore

devaprasedh.k@gmail.com²

Abstract

Described in this paper is a Self-Stabilizing Hybrid Bicycle. Gyroscope technology is implemented to develop the balancing forces to achieve stability on all terrains. The main principle revolves around generating the counteracting torque to help stabilize the tilting action of the vehicle. Along with this, we have introduced a hybrid system to prime the cycle when the rider is tired. The hybrid system includes a battery which can be charged by three different ways: Solar power, mechanical power from a dynamo from the pedal and an Ac supply charge. To charge the electric motor driving the bicycle, the energy from all these three paths is used. The hybrid-powered bicycle is built so that the rider can drive the bicycle in two ways, i.e. he can choose to use the electric motor entirely or he can ride it by himself manually which in turn charges the battery.

Keywords: Gyroscope, Self-Stabilizing, Renewable Energy, Safety, Hybrid Bicycle, Economic.

1. INTRODUCTION

As in present situation, with the rising number of vehicles, need for petroleum products is reaching its height. These fossil fuels are non-renewable and are likely to be lost in the future., so switching to alternative sources of energy is safer. More than one energy source is generated by the hybrid system to fuel a segment of the vehicle's propulsion. To power the motor and other auxiliary units and to charge the battery at the same time, solar power is used. The rechargeable battery can be used for a longer run as a backup power source. This project uses the BLDC hub motor as the motor. This program supports environmentally sustainable means of transportation. It also stands for the importance of conservation of fossil fuel resources.

Bicycles are a better transportation alternative, as they facilitate the use of fossil fuels. Owing to its light weight and manoeuvrability, it is

also beneficial. In the areas of repair and treatment, it needs very little focus. To generate the precise counteracting torque, an autonomous balanced bicycle uses sensors to detect the bicycle's roll data to carry the bicycle back to its upright position. In the past, several strategies have been applied, including the Gyroscopic Reaction Wheel, which we have chosen to assist the rider on the route.

2. Literature review

Hemashree Kakar et al [1], proposed the calculations for the designing of gyroscope and its related parts for the fully functional and its 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 [2], proposed the designing,

modelling, fabrication of a two-wheeler model to state the working of the principle of the gyroscopic couple for stabilizing purpose. The stability of the model is verified under various load by varying the gyroscope rpm.

Hao Dong et al [3], formulated that the wheel assembly of the locomotive is a rotor which itself has a 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, the gyroscopic contributory proportion is determined to concentrate on how the job the gyroscopic impact plays in solidness. Besides, the impact of the gyroscopic grid or gyroscopic terms pitch rotor idleness on the solidness coefficient is explored.

Rajendra Beedu et al [4], A DC hub motor mounted on the rear axle and solar panels mounted on its front carriage have been proposed to power the solar assisted bicycle. The battery storage will be charged by the panels and the hub motor drives the wheels in turn. This arrangement is used to replace the diesel engine, drivetrain & fuel system in the case of a two-wheeler. A 250W 24V hub motor will be considered for testing.

Rajneesh Suuhalka et al [5], He indicated that a bicycle was the necessary means of transport for many Indian villagers. Using either a dynamo or an alternator, the mechanical power generated by cycling can be transformed into electrical energy. This energy charges the battery and effectively enables the bike to drive the engine.

Chetan Mahadik et al [6], They also clarified the different facets, styles, techniques and studies to gain a deeper understanding of hybrid-energy bicycle riding. Here it addresses the use of solar, mechanical, and electrical energy to power the bicycle. This e-designed bike's is proposed and changes in the efficiency of the battery are addressed. The primary objective is to reduce pollution from the atmosphere and to have an affordable e-bike.

Rahul Sindhwani et al [7], the emphasis of this paper is on improving the performance of the E-bike. E-bike speeds are typically in the 40-45 km/hr range. Up to the limit. The speed of the E-bike is thus increased and the aerodynamic structure is planned in such a manner that the E-performance bike's is improved.

Kazusuke Meanaka et al [8], 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 a torsion bar. It can work adequately in the atmospheric pressure. This system also uses a semi-digital circuit system.

Yetkin et al [9], Where gyroscope stabilization of the control moment utilizes the reactive motion torque of an increased flywheel around an axis that balances the vehicle. They implement their system using a proportional-integral-derivative (PID) and sliding-mode controller (SMC) and evaluate the performance characteristics of their system. Their test results indicate that a single-axis gimbal flywheel CMG stability could be used to actively control inherently unstable bodies.

Ajinkya Parab et al [10], In this paper, the authors revealed that folds are really the strategic feature of the e-bike, that might not have been free of folding arms. For the convenience of sliding of the arms, a bolt is given. On the mainframe, a guide has been given to give the bike rigidity.

V Sankaranarayanan et al [11] the focus of this article is to build a torque-less sensor device for a hybrid human-electric bicycle. And use the disturbance observer, the user input torque is determined to create the device i.e.; controller for the motor to assist the cyclist depending upon the requirements. The efficiency of the closed-loop is guaranteed as per the standard for various assistance situations.

Pom Yuan Lam et al [12], This paper describes the design and development of a self-balancing bicycle using shelf-based electronics. An unstable non-linear mechanism equal to that of an inverted pendulum is a self-balancing bicycle. Experimental results showed the robustness and effectiveness of a proportional plus derivative (PD) controller attempting to balance the bicycle. As an actuator for the equilibrium, Control Moment Gyroscope (CMG) is used by the machine.

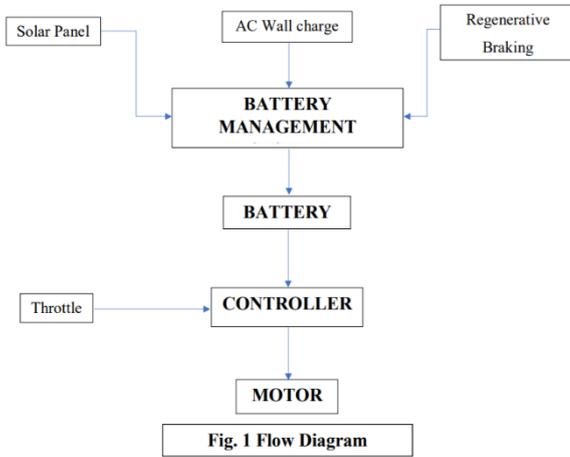
3. Existing system

3.1 Solar power augmented hybrid bicycle

Below are the key components needed to modify the conventional bicycle into a hybrid type bicycle.

- Frame
- Solar cell
- Motor
- Throttle
- Battery
- PWM Controller

Construction and Structure



For battery charging, it integrates solar power. Helped by the recovery of power from braking energy (human energy), solar energy, and the battery charge of the motor, the electric bicycle makes medium-distance riding much simpler. The wheel drives the engine. A battery-operated motor is used to power the bike, relying on generated solar and mechanical energy.

Connecting the motor to something like the rear wheel is necessary. The battery is charged in the light of day by solar energy while the hybrid electric bicycle is parked. On the bicycle carrier, the solar panels are maintained. The electrical motor attached to the rear wheel provides the data. The motor helps the resistance of pedaling while climbing hills. The battery can be charged by using the regenerative braking method for braking when heading down hills or when there is no sunlight. The pedals and motor are connected to the cycle using a double chain arrangement. The motor speed is adjusted using the throttle controller. Placing on the carriage the solar panel.

Motor Controller

This determines the bicycle's speed by adjusting the accelerator position. The applied voltage to the motor varies according to the environment by the use of the phase width modulator (PWM) technique. Monitoring of the cutting of the voltage supply to the motor in the event of unexpected disturbances and monitoring of the battery voltage are the duties of the

controllers (over-discharge). And as to the throttle position, the output voltage is changed by altering the PWM pulse width. The voltage of the output that has been changed is sent to the generator. The speed of operation of the engine is determined by the input to the motor.

Limitations

1. Regenerative braking system is a complex method when incorporated in an electric bicycle and it will not favor us in creating an affordable vehicle.
2. Double chain arrangement at the back wheel and installation of the motor at the back makes it over-packed and it also leads to complications and power-loss.
3. The motor used here is a BLDC motor which is coupled to the wheel using a double chain arrangement. This is less efficient when compared to the hub BLDC motor which we have utilized.

3.2 Gyroscopic self-stabilizing bicycle

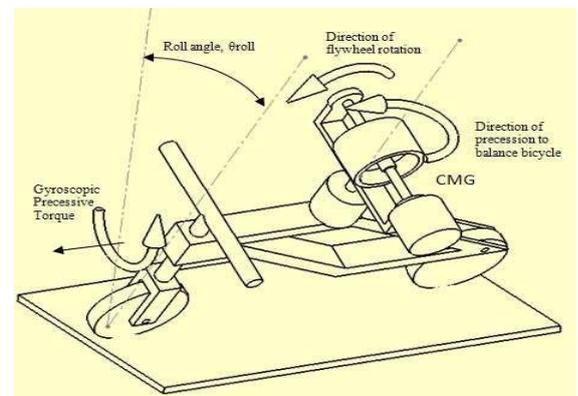


Fig. 2 Self-Stabilizer

Construction and Structure

In this system, they used the Control Moment Gyro (CMG). To balance the bicycle, the bicycle depends on gyroscopic torque. The roll angle will be detected by an IMU sensor as the bicycle rotates. This roll data is fed into an on-board controller that in turn guides the CMG's gimbal motor to rotate in such a way that a reaction torque is produced to stabilize the bike to an upright position. The computer utilizes a single gimbal engine for the translation of the CMG. The

induced axis torque and the direction of the output torque change are in accordance with the motion of the gimbal. To stabilize the bicycle, the machine makes use of gyroscopic torque.

Control Moment Gyro

CMG, also known as gyroscopic stabilizer, is a good option, as the reaction time is low and the mechanism can be stable even when the bicycle is stationary. The Control Moment Gyro (CMG) consists of a constant angular momentum spinning rotor, but by rotating the spinning rotor relative to the bike, the direction of its angular momentum vector can be changed. The spinning rotor is mounted on a gimbal, resulting in a powerful orthogonal gyroscopic reaction torque by applying torque to the gimbal for both the rotor spin and the gimbal axes. As it produces massive control torque on the bicycle with a small gimbal torque input, the CMG is a torque amplification device.

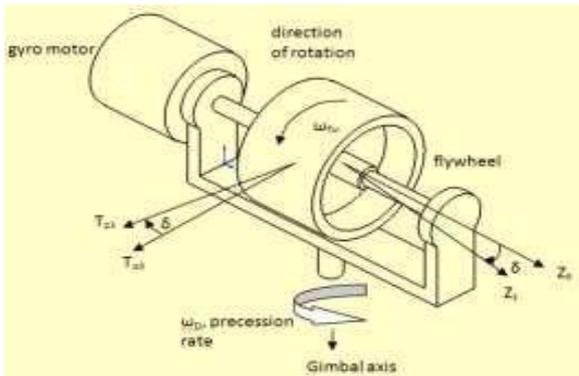


Fig. 3 Control Moment Gyro

Limitations

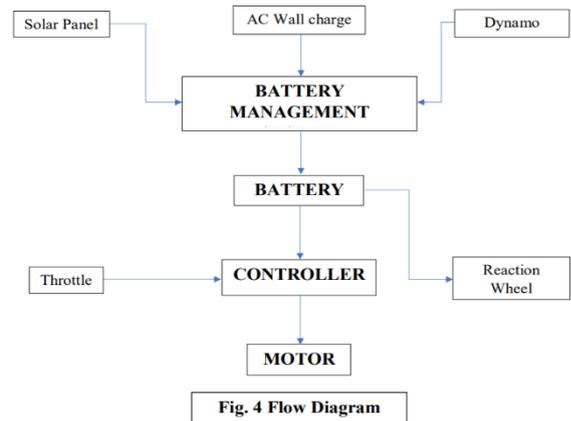
1. CMG method is the most expensive among the various methods used for self-stabilization.
2. CMG consumes a lot of power which in turn affects the energy efficiency of the bicycle.
3. CMG is advisable for autonomous vehicles but is not preferred for human-controlled bicycles and bikes.

4. Proposed system

4.1 GYROSCOPIC HYBRID BICYCLE

The proposed model that we have come up

with is a self-stabilizing hybrid cycle that uses human pedaling energy and electric motor as two ways of propulsion. The electric motor is powered by a compatible battery which is mounted on the cycle taking into account the variation of center of mass. The whole design of the vehicle is done, keeping in mind the system has to have an even distribution of weight/mass to support the working of the gyroscope.



4.2 Construction & structure

i. HUB MOTOR

We have incorporated a BLDC hub motor which is going to be mounted in the front wheel. This is an experimental idea, which has never been done before. We made this choice for a seamless weight distribution throughout the vehicle and for the reduction of complexity by avoiding a double chain arrangement. A suitable battery of same configuration is mounted on the bicycle chassis.



Fig .5 Hub Motor

ii. Solar panel

Solar panels are to be mounted at the back of the cycle on the carriage and also at the front. Solar panel can be mounted at the front by

fabricating a frame above the front wheel mud guard. Power from the solar panel is taken to the battery through the battery management system.

iii. Dynamo/alternator & BMS

An alternator or dynamo is utilized to make use of the rotational energy of the cycle wheel for charging the battery whenever and wherever there is no sunlight. A battery management system is necessary in order to collect the charging energy from both the solar panel and dynamo and use it to charge the battery safely without letting it to overheat.



Fig. 6 Dynamo

iv. Motor controller & battery pack

Motor controls are installed to regulate the motor. The motor is controlled based on the inputs from the triangular battery pack and the throttle signals sent to the motor controller that operates the bicycle in turn. The motor input determines the speed of operation of the engine. Throttle control is the part used in various riding situations to change the running speed of the bicycle. This is used to connect the accelerator and the pedal together.

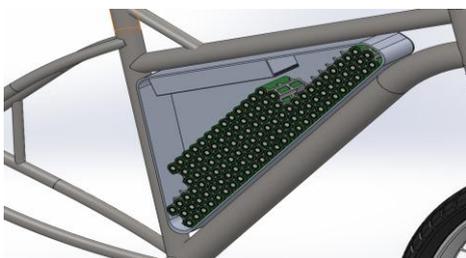


Fig. 7 Battery Pack

v. Throttle controller

For a motorcycle or scooter, the throttle controller is identical to the controller. The motor provides the bicycle with the corresponding power to push the bicycle forward by using the throttle. When no hands are placed on the throttle, the voltage going to the motor is less than 1V around the throttle, and thus there will be no motion in the bicycle wheel. The full voltage is given through the motor when hands are put on the throttle and fully twisted, so the speed of the cycle wheel will be at its peak. All other motions with the hands-on throttle between zero and max will provide variation, as per the control.

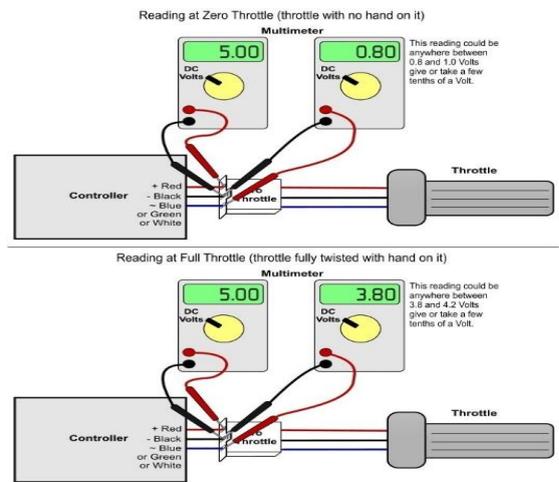


Fig. 8 Throttle Controller

4.3 Reaction wheel schematics

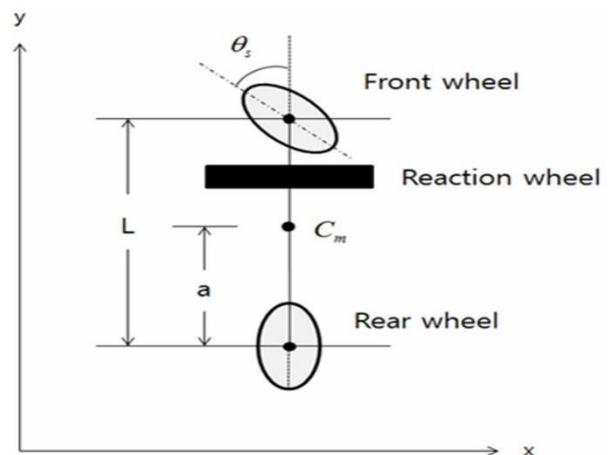


Fig. 9 Schematics

In this system, we have used gyroscopic reaction wheel to counteract the angular momentum caused due to the vehicular unstability. As depicted in the schematics, the reaction wheel will be mounted on the central rod of the frame keeping a small offset from the centre of mass (C_m), towards the front wheel.

The reaction wheel has a motor which keeps the wheel spinning and that output depends on roll angle of the vehicle, taking the axis of rotation along the upward direction. The principle behind this system is based on the law of conservation of angular momentum. This can be explained with an example, suppose the cycle is tilted in counter clockwise direction, the roll angle is detected and the motor powers the wheel to spin in the clockwise direction. When an equally opposite angular momentum is produced on the gyro wheel, the cycle is brought back to stability (upright position). This is done as a result of conservation of angular momentum.

Angular Momentum,

$$L = I\omega \text{ (kg.m}^2\text{/s)}$$

where, I – Moment of inertia

ω – Angular velocity

$$d\vec{L}/dt = 0, \text{ when external torque, } \tau = 0.$$

Table 1. Components list

SL. NO.	COMPONENTS	SPECIFICATIONS	QUANTITY
1.	Triangular Li-ion Battery Pack	24V	1
2.	BLDC Hub Motor	24V, 300-350W, 2400rpm	1
3.	Alternator (Dynamo)	12-48V	1
4.	Solar Panel		2
5.	Battery Management System		1
6.	Motor Controller	350W	1
7.	AC Wall Charger	220V	1
8.	Throttle Controller		1
9.	Gyroscopic Reaction Wheel		1

Conclusion

This project explains the possible ways of using all forms of energy in the most efficient way to power a bicycle for long distance travel. This project also covers the ways of adding rider assistance to provide safety and ease of riding. We have implemented this concept keeping in mind

the idea of bringing an affordable as well as reliable source of transportation, especially for the downtrodden.

We have combined two different technologies, that have been already implemented in the past, in an effective way to come up with an innovative and affordable means of transportation. This project is also a result of our concern about deterioration of environment and its causes.

Future scope

This system has a lot of points for innovative additives and supplements. Keeping in mind the affordability, we are intending to add the following features in the advanced prototype in future:

- Autonomous steering.
- Automatic Lighting Systems.
- 7 speed transmissions in manual mode.
- Automatic Tire Inflation System.

References

1. Hemashree Kakar. "Design Calculations of a Two-Wheeler Self Balanced Vehicle". International Research Journal of Engineering and Technology (IRJET). 2018; 05(07): 2066-2075.
2. 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.
3. 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.
4. Rajendra Beedu, Ankit, Mohmed Asif Shaik, Sushant Jain. "Design, fabrication and performance analysis of solar power bicycle". International Journal of Renewable Energy and Environmental Engineering ISSN 2348-0157, Vol. 02, No. 03, July 2014.
5. Rajneesh Suuhalka, Mahesh Chand Khandelwal, Krishna Kant Sharma, Abhishek Sanghi. "Generation of Electrical Power using Bicycle Pedal". International Journal of Recent Research and Review, Vol. VII, Issue 2, June 2014.
6. Chetan Mahadik, Sumit Mahindrakar, Prof. Jayashree Deka "An Improved & Efficient

- Electric Bicycle system with the Power of Real-time Information Sharing” Multidisciplinary Journal of Research in Engineering and Technology, Volume 1, No. 2, pp.215- 222, 2014.
7. Rahul Sindhwani, Punj L. Singh, Anjum Badar, Ankur Rathi, Design of Electric Bike with Higher Efficiency, International Journal of Advance Research and Innovation Volume 2, Issue 1 (2014) 247-251 ISSN 2347 – 3258
 8. 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.
 9. Yetkin, H., Kalouche, S., Vernier, M., Colvin, G., Redmill, K., and Ozguner, U., “Gyroscopic stabilization of an Unmanned Bicycle,” Stanford University.
 10. Ajinkya Parab, Ankit Kamath, SatwantSingh Rajpurohit, Zeeshan Mulla, Urban Electric Bike, IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 02, 2015 ISSN (online): 2321-0613
 11. V Sankaranarayanan, Sowmya Ravichandran. Torque sensorless control of a human-electric hybrid bicycle. 2015 International Conference on Industrial Instrumentation and Control (ICIC), 806-810, 2015.
 12. Pom Yuan Lam. Gyroscopic stabilization of a kid-size bicycle. 2011 IEEE 5th International Conference on Cybernetics and Intelligent Systems (CIS), 247-252, 2011.