SELF-STABILIZING BIKE USING GYROSCOPE

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Abstract

As the title of the paper gives rough idea of the paper, this research paper is about the new concept which if implemented on bike then bike can be balanced itself without any support. As every one of us is aware of the fact that bike needs support in standstill condition. So Gyroscope can help bike to balance itself. The main advantage of this technology will help us to cover up the bike with shed like fully packed bike same as car. If we're able to balance the bike automatically we'll be able to enclose the bike structure and we can make it air condition as well. This technology is generally used in heavy ships for balancing purpose to neutralize the effect of waves force. The same principle we can use with bike as well. Gyroscope is nothing more than a spinning wheel which has considerable mass having high angular velocity which generates balancing force opposite to the actual motion of body which is to be balanced.

Keywords: *Gyroscope, Self-stabilizing, Enclosed Bike, Control Moment Gyro etc.*

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1. INTRODUCTION

Bikes are mostly used for transportation within the same city and these are the most widely used and preferred way for transportation for short distance movement. There seems to be more scope for development in the field of Modeling and dynamics of bikes.

Bike shows different behavior in different conditions. When bike is in motion, bike can be stable. But vise-a-versa it's not possible when bike is in standstill condition. Purpose of this research paper arises here. We can balance bike in static condition using gyroscope principle device which is known as control moment gyro. CMG (Control moment Gyro) works as actuator. This technology is used in ships, airplanes, space stations and rockets etc for directional control or for directional sensing purpose.

Below image shows basic constructional diagram of control moment gyro. It consists of inner gimble, outer gimble, base and outing ring basically.

CMG (Control moment Gyro) control the angular direction of the entire device to which this CMG is mounted according to input given to heavy rotational mass rotating inside it at high speed. In-built motor is fixed in inside it which rotates that heavy mass. This entire unit is the combination of mechanical and electronic (PD controller and inclination sensor) components and devices which makes it possible. Sensor is required to detect the roll of the bike so that it can be corrected by means of CMG which are all inter-connected to each other. CMG is made up of spinning rotor and motored gimble that tilt the rotors angular momentum. As the rotor tilts, gyroscopic precession torque generated caused by changing angular momentum.

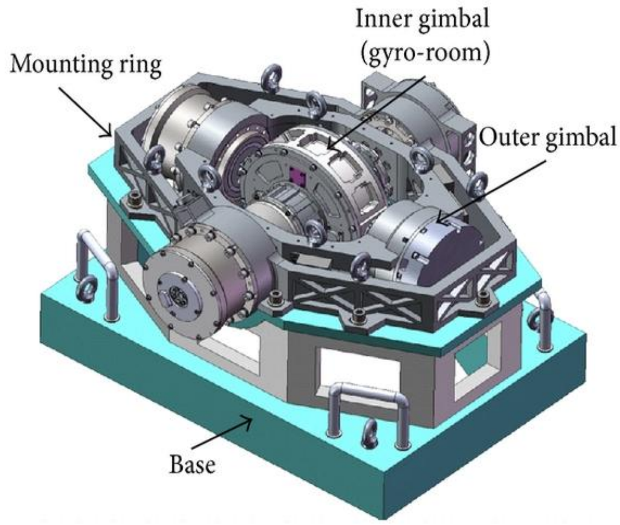

Fig.1.1: Control Moment [1]

1.1 How Gyroscope Works?

A gyroscope is a spinning mass arranged in gimbals which helps it to pivot in the x, y and z axis.

Consider a wheel is spinning about x axis with some angular velocity ω as shown in figure. Therefore angular momentum of the wheel is given by $L=I\omega$. This is the vector quantity as shown in spinning wheel figure.

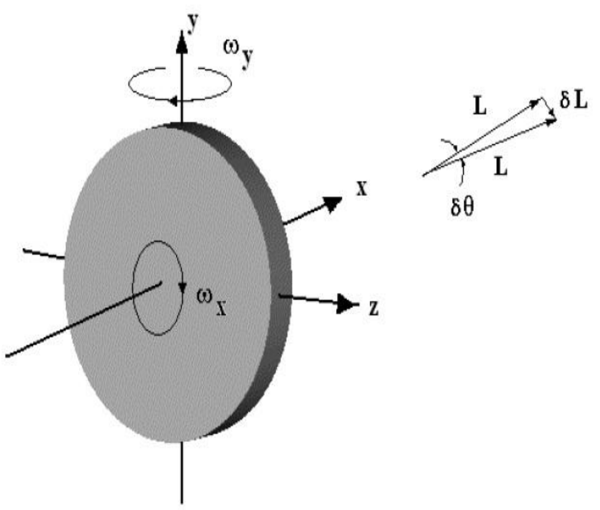

Fig.1.1.1: Spinning Wheel

Now consider, simultaneously, wheel is given a slight rotation in the direction of the y axis as well. In figure, as you can see, wheel is given short tilt of δθ.

The magnitude of L will be same but the direction of the vector after the rotation of y axis will be slightly different as shown in figure.

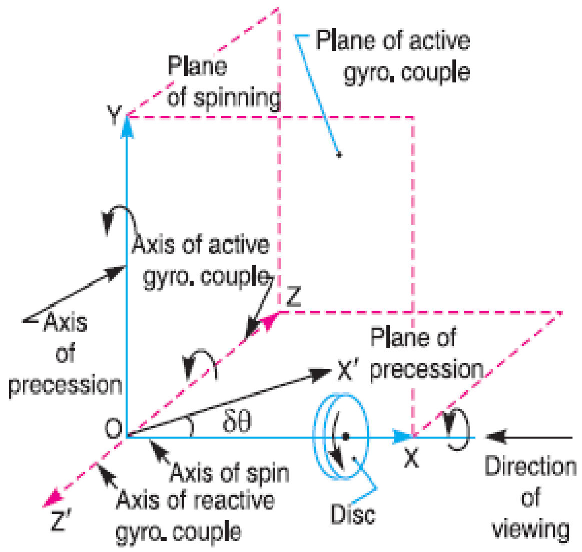

Fig. 1.1.2: Forces on rotating [2]

So change in angular momentum is given by:

$$\Delta L = \delta(I\omega).$$

Hence because of this change in angular momentum, because of inertia, a gyroscopic torque will act on wheel in z direction (amount of torque will see in next point). In short, a spinning disc given a small angular displacement in perpendicular direction, then it will experience a torque which will be in mutually perpendicular to those of two axes i.e. Z axis in this case.

Hence, all the role of three axes is as shown below:

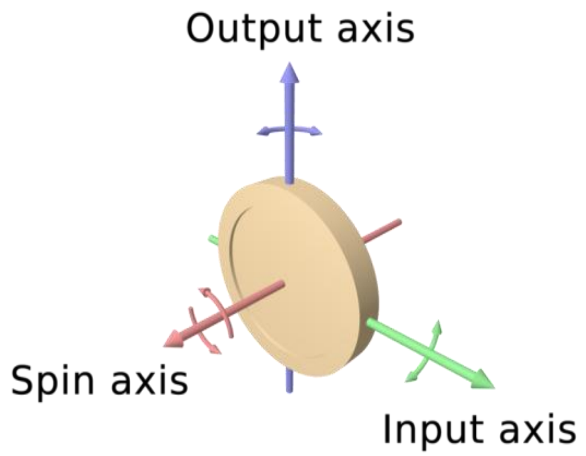

Fig. 1.1.3: mutually perpendicular forces[3]

X axis: Axis of rotation of wheel (spin axis)
Y axis: Axis of small angular displacement (input axis)
Z axis: Gyroscopic torque axis (output axis)

1.2 Gyroscopic Torque

Change in Angular momentum is given by:

$= \overrightarrow{ox}' - \overrightarrow{ox} = \overrightarrow{xx}' = \overrightarrow{ox}.\delta\theta$ … (in the direction of $\overrightarrow{xx}'$)

$= \mathrm{I}.\omega.\delta\theta$

And rate of change of angular momentum:

$$= \mathrm{I}.\omega.\frac{\delta\theta}{dt}$$

Torque applied to the disc causing the disc precession is given by:

$$\mathrm{T} = \lim_{\delta t \to 0} I\omega.\frac{\delta\theta}{\delta t} = \mathrm{I}.\omega.\frac{\delta\theta}{dt}$$

$$= \mathrm{I}.\omega.\omega_p \;\; \ldots \left(\therefore \frac{d\theta}{dt} = \omega_p\right)$$

From above equation, we get to know that torque we can generate on bike to balance is given by product of moment of inertia of rotating mass, angular velocity of rotating mass and angular velocity of tilting motion of the mass.

This concept is based on Newton's first law of motion i.e. every object tends to be in steady state or in the state of motion unless and until its acted by another force to change its state.

Therefore, rotating mass of the gyroscope resists the tilt of the wheel which results in the formation of gyroscopic couple.

Fig. 1.1.4: Mechanical Gyroscope

2. BASIC COMPONENTS REQUIRED

- **Heavy Rotating Mass**
  To generate reactive couple

- **Electronic Inclinometer or Electronic Gyroscope**
  To measure the angle of bike

- **Electronic Weighing Sensor**
  To measure the payload on bike to auto-adjust the rpm of rotating mass

- **Light Motor**
  To provide tilting angle to rotating masses

- **Electronic Controller System**
  To control the mass precession according to the bike inclination and velocity of inclination.

3. HOW GYROSCOPE CAN BE USED IN BIKE TO STABILIZE?

Now, let's look into how we can implement above gyroscopic principle to balance the bike itself. So, from above theory and equations, we got to know that if we give some input tilt to rotating mass it'll experience a mutually perpendicular rotating force on that mass. This principle can be used to balance the bike.

Please refer below workflow of the system to be implemented on bike. Firstly a heavy mass is attached to the frame of the bike which will be rotating at high speed. This heavy mass will act like a mechanical gyroscope which is our final output. Let's discuss this in depth further.

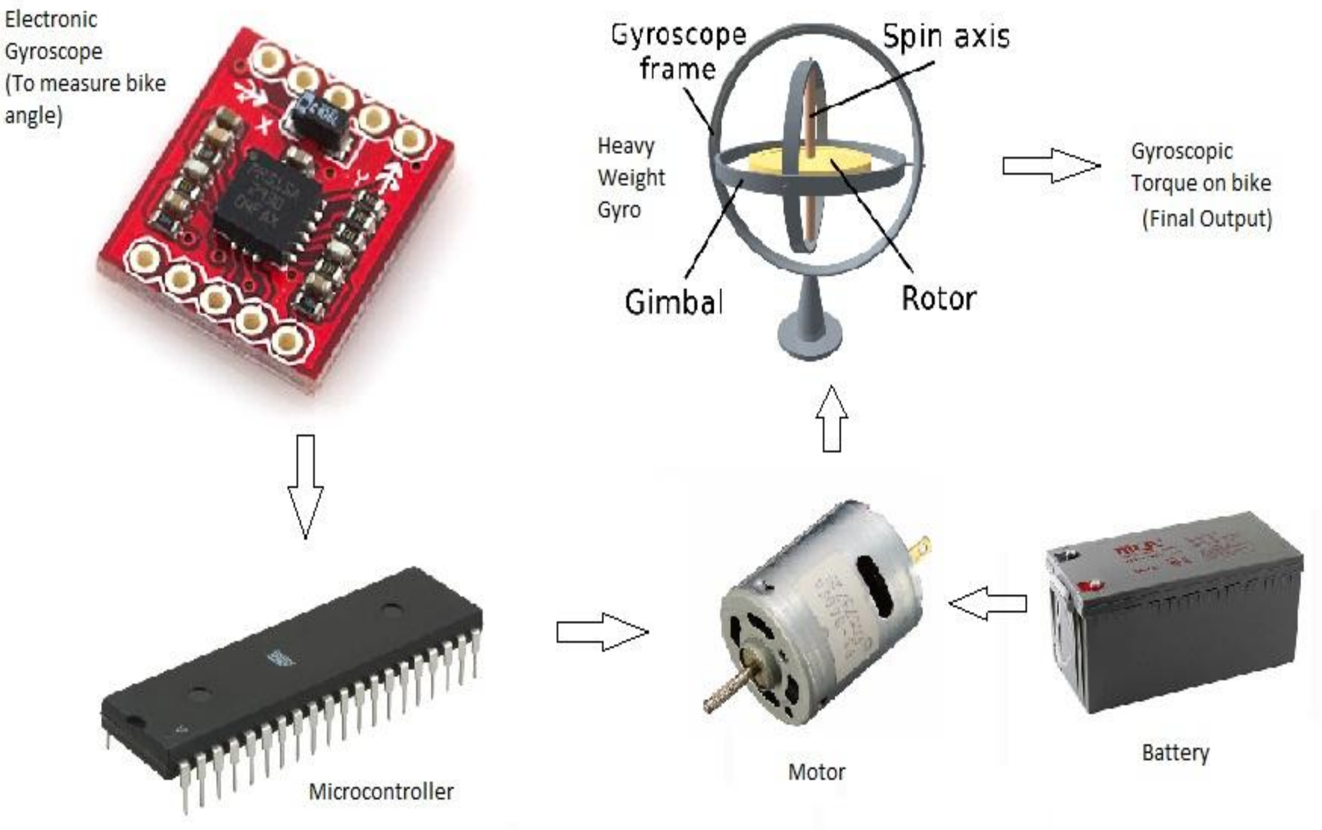

Fig 3.1: Working flow

Firstly, the heavy rotor is fit to bike chassis which will act as a gyro wheel. This rotor will have connected to motor which will give momentum to rotor continuously. Apart from that motor is again connected with other light purpose motor to provide tilting motion to rotational mass.

Now, consider that bike is trying to tilt right. The first thing electronic sensor will sense is angle of inclination with velocity and acceleration of tilting movement of bike. After sensing these details from the gyroscope sensor, this detail will get processed in microcontroller. Later, microcontroller will activate the motor which will tilt the rotating mass according to bike tilting velocity and acceleration. This tilting motion to rotor will produce anti-torque to bike’s tilting motion which will oppose bike inclination and will keep the bike in stable vertical position.

In addition to this, we need to compensate the speed of the rotor in accordance with weight of the user automatically because rider’s weight will affect the tilting torque of the bike. Hence if speed of rotor controlled automatically with the help of microcontroller, then we can manipulate and cancel out the bikes tilting torque with the equal and opposite torque on it.

Hence, by this way, we can take inspiration from ship stabilizing system amid water waves. By using this, we can make the bike fully enclosed from bottom as well which can be more comfortable travel experience. Please refer below diagram for explanatory purpose. Further research such as adaptive control can be added to the system so that the system can react to changes in payload.

4. CONCLUSION

From this research paper, we can conclude that, a CMG can be used very effectively on bikes for self balancing purpose inspired from ships and airplane. An enclosed bike is possible because of this technology which can make the ride more and more comfortable because of car like feature (like air conditioning) in it.

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