Gyroscopic stability of two-wheeler vehicles and testing of different materials for the gyroscopic disc

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Abstract: A number of factors such as maneuverability, convenience, affordability and reduced travel time have led to the emergence of two wheeled vehicles on Asian roads. In a complex transportation system, stabilized two wheeled vehicles will have higher safety as compared to the normal two wheeled vehicles. This stability can be provided by a Gyroscopic effect produced by a rotating heavy disc. If a two-wheeler moving on road is hit by another vehicle it goes off balance and may fall along with the driver. In such situations if a moving vehicle stabilizes itself then the safety of the driver is increased Dynamic stabilization of the vehicle is achieved by neutralizing the torque which causes unbalance by a torque which is produced by the included gyroscope. A stabilizing moment is generated by actively controlling the motion of gyroscope relative to the vehicle body. To study this we have designed a prototype of two-wheeler model. We test different materials on the prototype to find which material gives the best possible stabilization for a given set of dimensions.

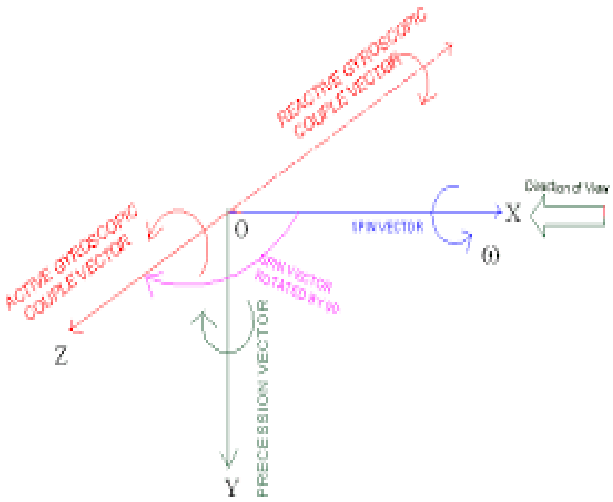
***Keywords* —balancing, dynamic stabilization, stabilization, stabilizing moment, two wheeled vehicles, gyroscopes.**

I. INTRODUCTION

A normal two wheeled vehicle is a nonlinear, multi variable and a naturally unbalanced, unstable system in terms of any impact or accidental situations. The widely used concept of gyroscope for stability of marine and air vehicles is proposed to be inculcated in the stabilization of the two wheeled vehicle in this paper. Stabilization of two wheeled vehicles is the need of the hour to provide utmost level of safety and revolutionize the maneuverability of the vehicle. The key point is to neutralize the effect of unbalance which is caused by the external torque or impact, by torque produced by the gyroscopic disc which is proposed to be used in the system. The torque causing unbalance or instability of vehicle does not remain constant and changes according to the road conditions. This implies that to generate equal and opposite reactive couple it is essential to vary the magnitude and direction of velocity of precession.

II. GYROSCOPE

Gyroscope is theoretically a device consisting of a wheel or a disc of heavy mass mounted such that it can spin rapidly about an axis which is itself free to change direction. The orientation of the axis is not affected by tilting of the mounting, so gyroscopes can be used to provide stability or maintain a reference direction in navigation systems, automatic pilots and stabilizers. Gyroscopes are also based on other operating parameters such as electronic, microchip packaged MEMS gyroscopes. These devices find their applications in inertial navigation systems, stabilization of ships unmanned aerial vehicles and so on.



A. Gyroscopic Principles

The ability of a freely rotating mass to maintain its plane of spin when an external force is applied comes from its rigidity. The gyroscopic couples can be categorized into two types namely- The active gyroscopic couple and the reactive gyroscopic couple

Active gyroscopic couple- The couple which must be applied to the disc across the axis of spin to cause it to precess in the horizontal plane about axis of precession is called active gyroscopic couple.

Reactive gyroscopic couple- The couple which causes the axis of spin to precess and the shaft on which disc is

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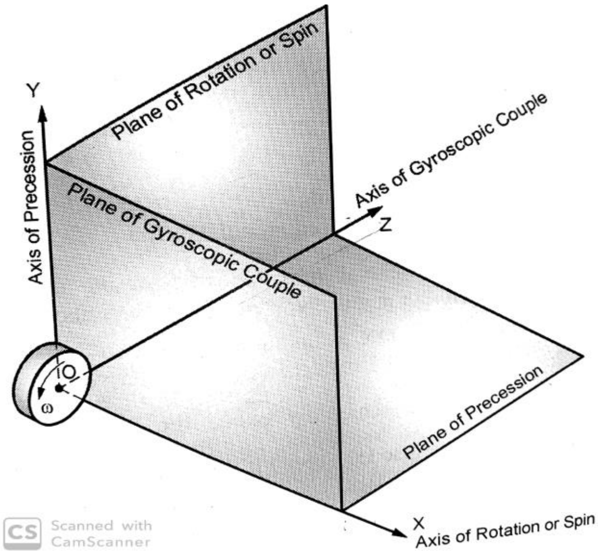
mounted applies gyroscopic couple through support bearings, to the frame.

B. Gyroscopic effects

Whenever a body is rotating or spinning in a plane (YZ) about an axis (axis OX) and its axis of rotation or spin is made to precess in an another perpendicular plane (plane XZ), as shown in figure below, a couple is induced on the rotating or spinning body across the axis of the rotation or spin in a third mutually perpendicular plane (plane XY)



Conversely, whenever a body is rotating in a plane (plane YZ) about an axis (axis OX) and a couple is applied on the rotating body across the axis of the rotation or spin in another perpendicular pane (plane XY), the rotating or spinning body starts precessing in a third mutually perpendicular plane.

The above stated effects are known as gyroscopic effects. The two things which are necessary for existence of gyroscopic effect are- rotating body and force or a couple trying to change the orientation of the axis of rotation of rotating body.

The magnitude of reactive gyroscopic couple is

$$C = I\ w\ wp$$

Where,

I- Moment of inertia about an axis of rotation, kg/m2

w- Angular velocity of the disc, rad/s

wp- angular velocity of precession, rad/s

III. Gyrovehicle Model and Methodology

This model's objective is to prove the fact that a two-wheeler vehicle can be stabilized using a gyroscopic disc and further to test and compare different disc of different material and varying masses and to compare the results. Gyroscopic principle is used in the said prototype and the gyroscopic phenomenon can be witnessed in the model.

The described gyrovehicle is a scaled model or a prototype which has been designed and manufactured, disc of different material and sizes are currently being used to test the concept and compare the result. It is the primary objective of the model to prove the principle of providing stability to two-wheeler vehicle by a gyroscopic model in impact situations. Further the secondary objective is to test this gyroscopic effect on small model with some iterations in masses and material and compare the results.

The prototype was created using following parts:

1. ABS polymer Frame
2. 12V DC Motor
3. Mild steel disc
4. Aluminium disc
5. 12 V Battery
6. Rubber Wheels
7. Nuts and bolts

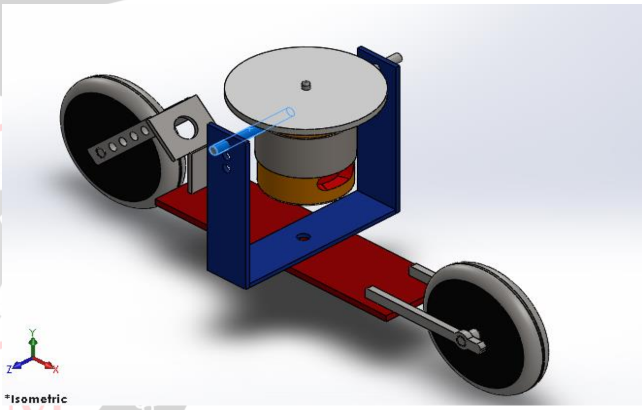


Fig.1: 3-D model of the Gyrovehicle

The model is 22cm long, 8cm wide and 9cm high. To keep the model weight lower it is made from low weight polymer. Two types of gyroscopic discs are tested: MS disc and Aluminum disc. Both the disc used are identical in dimensions, diameter and thickness are same while density and weight are different.

The methodology used is in first set MS disc and Aluminum disc of same diameter and thickness are tested, reason being to test two identical disc of different material and density. the gyroscopic principal requires heavy disc for proper functioning, hence the results of two disc are compared and material with more accurate results can be selected. Then the material with better results is tested for varying thickness with different disc the second set of reading. In both the sets readings are taken at two different speeds. To demonstrate actual impact like conditions, impact is given by hand force and the angle up to which gyroscopic effect is generated are recorded.

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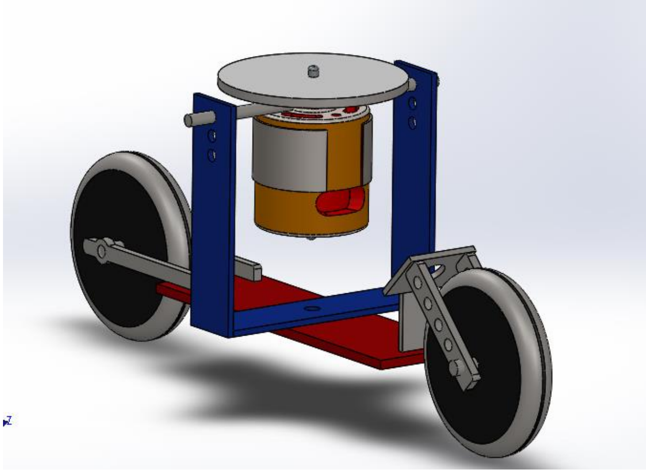


Fig.2: Isometric view of Gyrovehicle

For the model a 12V DC motor of 300RPM is used. The motor is mounted on a cross bracket with the help of two small shafts which are free to rotate in the slot provided. Also to adjust the height and center of gravity more slots are given for mounting the motor. The motor mounted bracket is firmly bolted to the base or the body of vehicle. This bracket is mounted in transverse direction so as to produce the desired gyroscopic effect. This arrangement helps the gyroscope to balances the side impact of any vehicle and produce the gyroscopic effect, further it transfers this effect to the vehicle body and balances the vehicle.

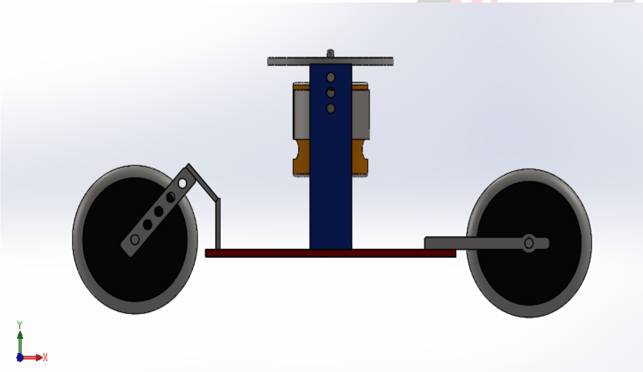


Fig.1: Side View of Gyrovehicle

Although the described model is not exactly same as a real life vehicle, it is designed to study the gyroscopic effect and variations of this effect for different materials.

IV. Testing of Materials for the Gyroscopic Effect

The materials used for the gyroscopic disc are Mild Steel and Aluminum.

First the two discs of same diameter and thickness but of different material are experimented at two speeds of 250rpm and 300rpm. The motor is turned on and then the vertically balanced vehicle is given impact force by hand just enough to cause a tilt of the vehicle and the readings are taken for the angle up to which the gyroscopic effect is observed. Few such readings are taken and average of these is found out, this is because creating an impact like condition is done by trial and error by applying force through hand and allowing the vehicle to stabilize itself.

(All calculations are done considering rpm of precession as 30 rpm and speed of the rotating disc as 300rpm)

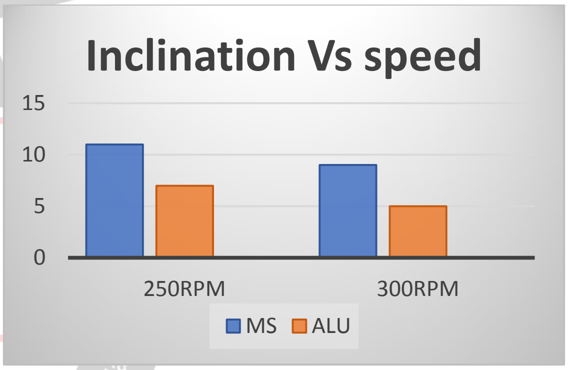
1. Aluminum Disc: It weighs 31.17 grams and is of the radius 3.5 cm

$$m = 29gm = 0.029kg$$
$$r = 3.5cm = 0.035m$$
$$I\ w\ wp = 0.00476522\ N - m$$

2. Mild steel disc 1: It weighs 91grams and is of the radius 3.5cm

$$m = 91gm = 0.091kg$$
$$r = 3.5cm = 0.035m$$
$$I\ w\ wp = 0.0216611\ N - m$$

The following chart shows the average value of the angle up to which the gyroscopic effect is observed at two different speeds for both the materials.



Graph 1: Tilt angle for MS and AL disc at two different speeds

From the graph it is clear that at both the speeds MS disc shows more gyroscopic effect due to its heavy mass, for the two discs being identical. Aluminum has lower mass than MS and MS shows better results. Hence it can be concluded that for the model in consideration MS disc should be selected, this can also be implied to actual two-wheelers with further calculations.

Now for the second set two discs of same material, same diameter but of different thickness are experimented.

The MS disc showed better results in first set of experiment, now same disc for different mass and thickness are experimented.

Mild steel disc 2: It weighs 60grams and is of the radius 3.5cm

$$m = gm = 0.060kg$$
$$r = 3.5cm = 0.035m$$
$$I\ w\ wp = 0.0176611\ N - m$$

The following chart shows the average value of the angle up to which the gyroscopic effect is observed at two

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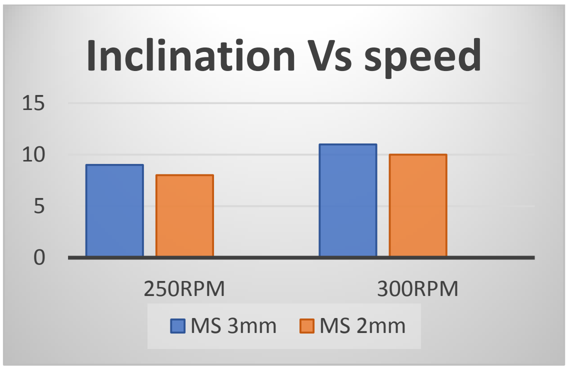
different speeds for both the disc of same material but different thickness.



Graph 1: Tilt angle for MS disc with different thickness.

It can be concluded from the graph that for same size of disc more is the mass more is the gyroscopic effect produced and vice versa. Also, for same material and diameter, more is the thickness better is the gyroscopic effect produced. Here it can be concluded that for condition of space constraints out of two identical disc, one with greater thickness shows better results. Hence it can be applied that for two-wheelers with space constraints disc of higher thickness can be preferably used.

V. Conclusion

As shown above we have successfully proved that using a gyroscope model stabilization of two wheeled vehicles can be achieved in case of impact or accidental situations. Hence it can be used as a safety device in two-wheeler vehicles . We have also tested different materials for the disc and hence the most suitable material can be found out.

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