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Development of Self Balancing Prototype of Two Wheeled Vehicle by Using Gyro Stabilizer

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Abstract- **Gyrostabilizers are anticipated to be as appropriately desired system to provide stability for two wheeled vehicles. This paper focuses on the concept of developing the two wheeled vehicle prototype to exhibit the working of gyrostabilizer (or gyroscope) for providing stability. The stabilization of two wheeled vehicle works as torque applied externally on vehicle is neutralized by torque produced by gyroscope. When torque is applied vertically on the gyroscope normally to its spin axis, this causes to develop precession motion which process the gyroscope along its perpendicular axis. As following, the torque developed by gyroscope will counter the applied torque causes vehicle to be in equilibrium (i.e., gyroscopic effect). This paper exemplifies the latter described system in static condition. But, the paper also introduces further the development of the vehicle in dynamic condition. In this system, sensors with modified gyro wheel are implemented. Sensors actuate the gyro wheel according to the tilt of the vehicle to provide same magnitude of the torque exerted, externally.**

***Index Terms*— Gyrostabilizer, Gyroscopic effect, Precession motion, Static condition.**

I. INTRODUCTION

Two wheeled vehicles do not have enough point of contact to stabilize themselves [2]. To provide directional stability, gyroscopic effect has been widely used in several terrain vehicles such as land, sea and space. Gyrostabilizers have been used for attitude control of vehicles in many situations such as in underwater vehicle, Bicycle, Monorail, Robots and Control Moment Gyroscope (CMG) [6] used in spacecraft for motion control.

In recent period, Gyrostabilizer systems are anticipated to become widely adopted in land vehicles to provide better stability by reducing extraneous supporting wheels from vehicle. It helps to develop the vehicle with economical advantage of assisting the cars to take sharper curves with using low space and low cost in manufacturing and maintenance. Inline or two wheel vehicles offer high efficiency than four wheel cars. This increased efficiency is mainly due to reduced weight, fewer friction surfaces and reduced drag.

Two wheel vehicle with gyrostabilizer can be demonstrate as- Consider a disc rotating in X-axis (in ZY plane) and its axis of rotation is forced to precess in one of its perpendicular direction (.i.e., about Y-axis or XZ plane).

The couple induces, will act on the third perpendicular plane (i.e., XY plane or about Z- axis). This couple caused by the phenomenon called as gyroscopic effect and the couple induced is known as reactive gyroscopic couple. On the other hand ,this phenomenon can be defined as- When the torque (gravity or excitation moment) is applied to an axis normal to the spin axis, causing gyroscope (disc) to precess, a moment is produced about the third axis which is orthogonal to its spin axis or applied torque[4].

This tendency of a rotating body about an axis of symmetry offers resistance to change in its direction of axis of spin is due to change in rate of change of angular momentum of the body [1]. The reactive gyroscopic couple is the product of change in angular momentum. This change of angular momentum (i.e., cause of precession of spin axis) is known as active gyroscopic couple. This resultant reactive gyroscopic couple will be equal in magnitude but will be opposite in direction of active gyroscopic couple. This overall describes the phenomenon provides an effective means of motion control.

This similar concept to stabilize the inline wheel vehicle was developed by Louis Brennan in 1905[3] as monorail but that was unable to commercialize due to safety and design complexity [3]. This paper concentrates over the specific manner of motion control on vehicle in rest condition.

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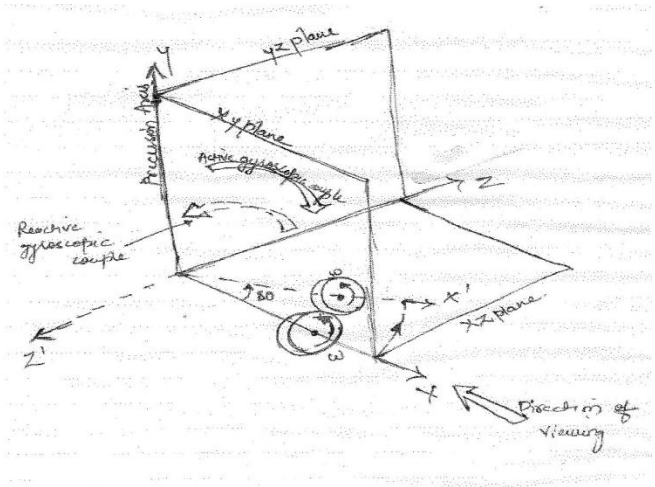

1: Basic illustration of Gyroscopic Effect [4]

II. CONCEPT GENERATION

This paper is based on the concept of stabilization of two wheel vehicle in idle condition. This could be exemplified by using gyroscopic effect on suitable prototype of two wheel vehicle.

A. Construction

This prototype is made up of an in-house material which was easy to obtain and reduces the overall experimental cost. And, I had to build two prototypes because first was failed.

This prototype is created by following parts as:

1. Wooden plank as base
2. Plastic scale as frame for gimbal support
3. Four fixed compact disc as gyroscope flywheel
4. DC motor as power supplier
5. Wooden pencil as Gimbal
6. Rounded surface wheel

1. Base and Wheel Support

Base support for the prototype should be able to endure the stress and vibration occurs while experimentation. Firstly, the base support provided to the prototype was too heavy which caused unable to stabilize the vehicle. Then, lighter wooden plank was used which was able to endure the stresses and of less weight. Therefore, it is necessary to choose as much as possible lighter material to provide better stability.

Wheel is bolted into wooden plank. In first prototype, I used the wheel which was of approximately 4.5 cm diameter with slightly rounded surface. This causes the prototype to stand vertically without any support and reactive couple. When the motor starts, it felt down due to higher centre of gravity caused by larger height of wheel and reduces the ability of gyrostabilizer of stabilization. Therefore, wheel should be well rounded on surface and of fewer diameters. Thus, I used wheel of 2cm diameter in second prototype.

2. Gyroscope or flywheel and Frame

The most significant device in the prototype is gyroscope or flywheel. For a specific vehicle weight and centre of gravity (COG), a flywheel should be of suitable size so that the vehicle's vertical stability may be indefinitely while in idle condition. The major variables of this component are diameter, thickness and mass. In this prototype, four compact disc are of enough mass to provide the appropriate moment of inertia for resultant couple.

Plastic frame is used to provide the support for gimbal. Plastic material is lighter and able to withstand on stresses and keeps the whole vehicle lighter. This plastic frame is made up of plastic scales joined by L-shaped supports.

3. Motor and Gimbal

Motor provides a torque which is essential for gyroscope to produce a reactive couple. Therefore, Motor possess variables i.e., torque and mass which can affect the obtained result. Motor is fitted on the top of the gimbal and it is the heaviest part of the vehicle. Therefore, Centre of Gravity (COG) of the prototype lies on it. The speed of the motor plays vital role on the gyroscopic effect. Thus, speed of the motor should be more as much as possible (to a specific point).In this prototype, motor can spin up to 3000 rpm with 12V power input. This motor is small in size and supplies enough amount of rotation.

Motor is supported by a gimbal i.e., wooden pencil. Aligned holes were drilled in the opposite faces of the frame. Bearings are used to provide the rotation for gimbal about the axis, perpendicular to the spin axis of flywheel. This helps to provide precession motion on the gyroscope.

4. Other several considerations

Mass of gyroscope plays a vital role in stabilization of prototype. Angular momentum and Mass of Inertia depends on the mass of gyro or flywheel. But, vehicle width, vehicle thickness, gyro width and gyro thickness are the parameter that do not affect the stabilization i.e., their effect is negligible. Centre of Gravity of vehicle, gyro and motor varies the ability of stabilization of vehicle [2].

Therefore, to obtain the desired result of the system, it should be considered that [2]:

- Centre of Mass of the cart should be as low as possible .
- Centre of Mass of the gyro should be as low as possible.

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- Rotation of the gyro should be increased as possible, up to specific limits.
- Decrease the mass of the gyro(to a point)

B. Working

In this prototype, the motor is fitted downwardly on the gimbal. This whole core as heaviest part represent as Centre of gravity which tries to attain the position and move downward. But, the gimbal has fitted on the frame and bearing allows gimbal to rotate about the axis (in the rolling plane of vehicle).Therefore, motor can only lean forward or backward about the gimbal. So, when motor starts rotating external excitation or active gyroscopic couple occurs. This gyroscopic couple occurs due to falling of vehicle on its one of a side. A motor started, falls either on forward or backward, causes the precession motion for gyro or flywheel. Due to this precession of the spin axis, reactive gyroscopic couple acts on the frame which is equal on magnitude and opposite in direction to the active gyroscopic couple and stabilizes the vehicle. The vehicle attains the equilibrium state while in an idle condition.

III. THEORETICAL DESCRIPTION

Consider a disc of mass moment of inertia (I) to be spinning with angular velocity ω about the axis OX in clockwise direction as seen in the direction from O to X. The plane of the disc is normal to the X axis. As shown in Fig.2 , let the axis of disc rotate about Y axis in the plane XOZ as to occupy a new position OX' after a short interval of time Δt. Let, the angle XOX' be equal to Δθ[1].

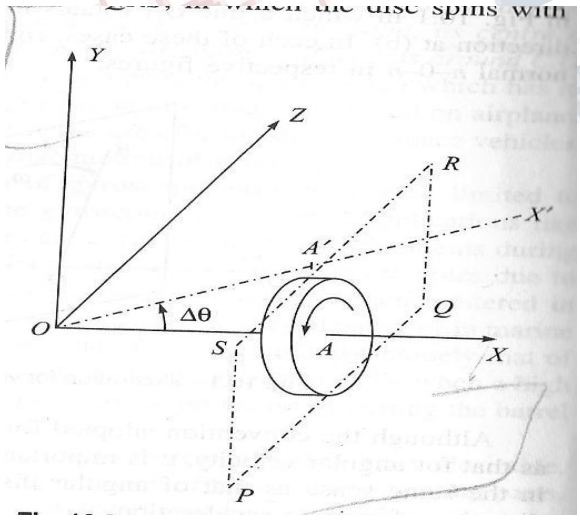

Fig 2: Precessional motion of a disc[1]

The mass moment of inertia can be expressed by $I = mr^2$. Then,

Angular momentum can be given by $I\omega^2$.

As shown in fig2, the axis of spin has precessed through an angle Δθ=∠XOX'.

The sense of angular velocity vectors, as obtained by applying right hand screw rule to the disc in two positions, as shown in Fig.3(b.)

In vector triangle,

- Vector oa represents an angular velocity, ω.
- Vector ob represents an angular velocity, (ω+Δω).
- Vector ab represents a total change in angular velocity, both in magnitude and direction.

As shown in Fig3 (b), ac and bc are the components of ab and mutually perpendicular to each other. Component ac presents increase in magnitude of angular velocity while component bc presents change in direction of angular velocity.

As we know that couple or torque is necessary for producing an angular acceleration in a rotating disc. This angular acceleration represents change in angular moment and produces precessional motion[1].

Therefore, Change in angular momentum can be represented by, ab=Δ(Iω)

And, the rate of change of angular momentum produced by gyroscopic couple C can be given by[1],

$$C = \lim_{\Delta t \to 0}\left(\frac{ab}{\Delta t}\right)$$

But, ab ≈(oa)Δθ (for small angleΔθ).And the line ab is assumed to be perpendicular to oa, as shown in fig.3 (c).

Hence, From above equation, $C = (oa)\frac{d\theta}{dt}$

Or, $C = (oa)\omega_p$

Or, $C = I\omega\omega_p$ (Since, oa = Iω)

This above equation represents an active gyroscopic couple and also represents the counter couple or torque of gimbaled flywheel assembly [1].

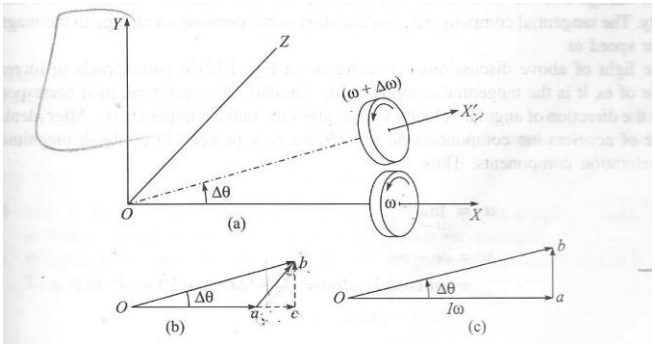

Fig 3(a): An illustration of angular speed of a disc with time[1], Fig 3(b): Angular velocity vector diagram[1], Fig3(c):An illustration of vector diagram when angular

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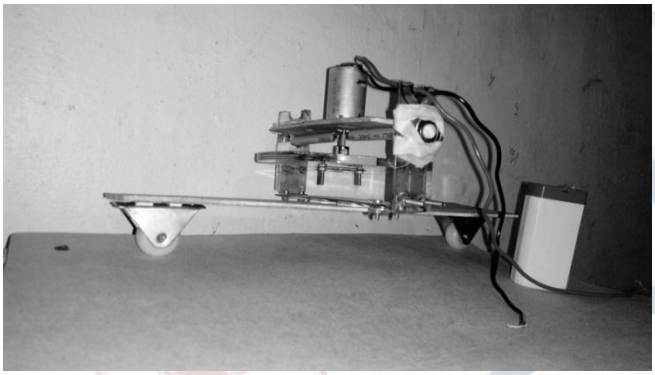
velocity remains constant[1].

IV. OBSERVATION

When the prototype (as shown in Fig.4) achieve the state of equilibrium i.e., stabilizes. But, it starts to oscillate at certain frequency. This phenomenon occurs due to cheap and flexible material. And, Compact discs are difficult to fix together and balance properly. This shaking was also due to improper calculation of each aspect of manufacturing the prototype. The other problem came out that the motor or gyroscope sometimes turns around completely about the gimbal axis. This situation came because gyroscopic effect becomes less effective after the specific angle (approximately 90°) of rotation around the gimbal axis.

However, the main objective of the prototype to demonstrate the ability of gyrostabilizer to stabilize the inline or two wheel vehicle is achieved successfully.



: Final Prototype of Two Wheeled Gyroscope(Side view)

As mentioned, I have made two prototypes due to failure of first prototype. To accomplish the desired goal, I made some changes in second prototype such as:

1. I replaced 1000rpm 12V DC stepper motor with 3000 rpm 12V motor because 1000 rpm was less capable to provide sufficient rotation for angular momentum.
2. I have trimmed the upper portion of frame to make vehicle lighter and, also replaced heavy and thick wooden base from very thin wooden plank base.
3. Replaced a large diameter wheels with small diameter wheel to reduce the height of the vehicle.

V. GYROSTABILIZER APPLICATION IN DIFFERENT FIELDS

A. *Types of gyrostabilizer implemented in various vehicles*

The first recorded construction of gyroscope device was in 1817[5]. Since, gyroscope has been implemented in many systems for several purposes. Marine vehicles and spacecraft are the primary vehicles in which gyrostabilizer have been used. But, implementation of gyrostabilizers in wheeled vehicle has also started. In marine vehicle, gyrostabilizers have been used to attitude control or to control orientation specially roll motion control. In spacecraft, it has vital importance to control orientation of vehicle with low energy consumption

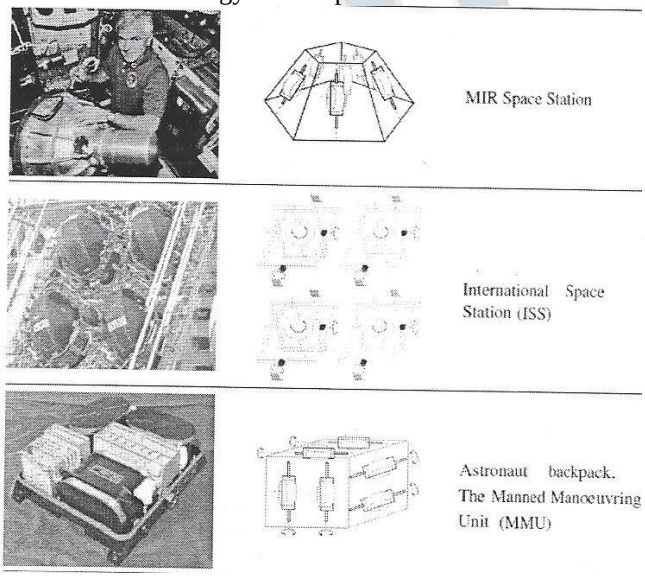


Fig5: Space gyro stabilization systems[5]

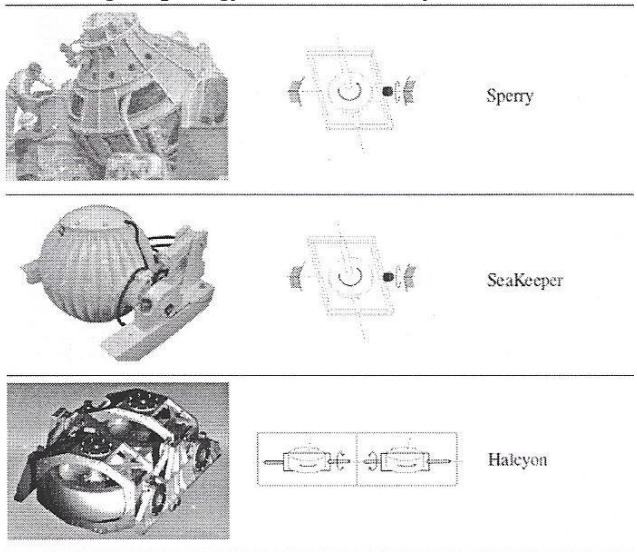


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Fig6: Marine gyro stabilization systems[5]

In wheeled vehicle, gyrostabilizers were used to stabilize the vehicle on two or one vehicle to reduce the unnecessary space like in Ford Gyron, Brennan monorail, Gyrover, etc. In fig.5, Fig.6, Fig.7, various gyrostabilizer systems have been showed which has been used.

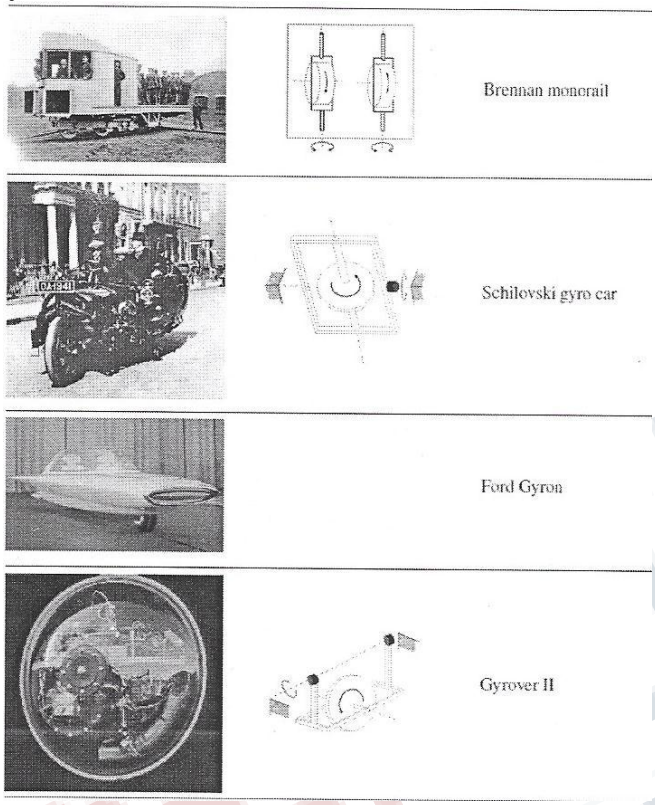

Fig7: Wheeled vehicle Gyrostabilizer systems [5]

B. Future prospect

Gyrostabilizer has been developed with modern technological aspect which allows it to use safely in vehicles. Now, it has started to be used in two wheeled vehicle for future transporting aspects such as lit motors C-1, Hoverboard etc.

Fig.8: Lit motors concept bike(Exploded Image)

Lit motors concept bike C-1 offers the features of bike and car together. This vehicle works on the concept of above illustrated prototype in many aspects. But this vehicle uses two gyro wheels which have been precessed by the sensors according to its rolling movement. This sensor provide aid to several microprocessor to know the exact magnitude of the precession of spin axis of gyro wheels to induce the equal amount of reactive gyroscopic couple for stabilization for both static and dynamic motion.

VI. CONCLUSION

Gyroscopic stabilization has used widely to stabilize the variety of systems. As proved in this experimentation, this technology can also be used for stabilization of two wheeled vehicle in idle condition. However in dynamic condition, the stabilization can also achieved by gyrostabilizer as used in Lit motors C-1 vehicle by using sensors , microprocessor and feedback system. This paper also addresses the several applications of gyrostabilizer which provides better configuration to analyze its aspects.

And, the stabilization of an in-house built prototype of two wheeled vehicle was validated by the gyrostabilizer by using gyroscopic effect.

REFERENCES

[1] Ashok G. Ambekar, “Mechanics and Machine Theory, PHI Publications, pp. 404-442.

[2] Temitope Akinlua, Dmitriy Dryga, Adam Gunnett, Jon Montague, Elobuike Oji, "Gyroscopic stabilization of unstable vehicle," Team#2, Department of mechanical,University of Michigen, Ann Arbor, Winter 2007 .

[3] Stephen C. Spry, Anuock R. Girard,"Gyroscopic Stabilization of Unstable Vehicles: Configurations, dymnamics, and controls," Vehicle system Dynamics, May 2008.

[4] Akshay Khot, Nishad Kumbhojkar, "Modeling and Validation of Prototype of self stabilizing two wheeler using gyroscope",IJARET,vol 5,pp.48-54.

[5] Nicholas C. Townsend, Ramanand A. Shenoi, "Gyrostabilizer Vehicular Technology", Applied Mechanics Reviews,January 2011.

[6] Andrew Boddifordn, Charlie Manion, Kwan Suk Kim, Pradeep Radhakrishnan, Luis Sentis, "Experimentation to validate the use of a control moment gyroscope (CMG) to turn robots, ASME 2013 International Design Engineering Technical Conferences & Computers and Information in Engineering Conferences, August 2013.