VOLTA: Self-Balancing Electric Bike

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Abstract— The project focuses on the concept of developing a two wheeler bike & it's validation with the help of a model. The project deals with an experiment carried out to produce gyroscopic effect on the model. The model is a two wheel vehicle in which rotating discs imparted act as gyroscope to produce a counterbalancing force i.e. gyroscopic effect when the vehicle model loses balance on either sides. Thus the vehicle stabilizes itself. Wherein even if an external force is applied to the system the gyro sensors deployed in it sense the force and develop a force of similar magnitude but in opposite direction due to presence of two gyroscopes used in the vehicle, thus the vehicle does not lose it's balance even if the external force is applied to it.

Key words: Self Balancing Vehicle, Gyroscope, Inverted Pendulum, Reaction Wheel

I. INTRODUCTION

Volta is an idea presented by our team. Volta is going to be an electric bike which can "Balance on its own". Yes you read it right. Self-balancing bike!!! Self-balancing an electric bike is a concept which uses the principles of gyroscope and reaction wheel and concepts of inverted pendulum. We have referred to a number of research papers, case studies and number of websites and blogs to come to a conclusion that self-balancing will be possible using gyroscopic reaction and design it in such a way that the precision of the gyroscope creates an opposing couple to the unbalanced tilt of the body. The key idea is the motion of the gyroscope relative to the body is actively controlled in order to generate a stabilizing moment. The model works on the principle of inverted pendulum. The construction process includes the designing of the model in software, fabricating the model, assembling the model and testing.

II. PRINCIPLE

It works on the principle of inverted pendulum and employs the use of electro- mechanical components which can be used as a means of transportation for a single person. The two-wheeled, self-balancing vehicle is a non-linear multi-variable and naturally an unstable system. Controlling such a system is a hard task and thus it is the topic of research. One of the solutions is Control moment gyroscope (CMG).

This method can provide a large torque, but energy consumption of CMG is very high because the flywheel is spinning all the time. The CMG consists of a spinning rotor with a large, constant angular momentum, whose angular momentum vector direction can be changed for a bicycle by rotating the spinning rotor. The spinning rotor, which is on a gimbal, applies a torque to the gimbal to produce a precession, gyroscopic reaction torque orthogonal to both the rotor spin and gimbal axes.

A CMG amplifies torque because a small gimbal torque input produces a large control torque to the bicycle.

#GYROSCOPE A gyroscope is a spinning wheel or disc in which the axis of rotation is free to assume any orientation by itself. While rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum.

1) First Law of Gyroscope: If a rotating wheel is so maintained as to be free to move about any axis passing through its center of mass, its spin axis will remain fixed in space.
2) Second Law Of Gyroscope: When a torque acts on a spinning mass with an axis perpendicular to that of spin, then the latter will precess about an axis perpendicular to both aforementioned axes, at an angular velocity, Ω,=T/I*ωs..

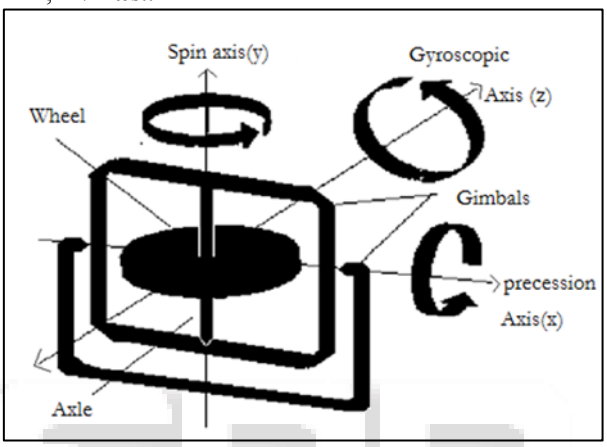

Fig. 1: Principles of Gyroscope

Thus, for the stability of such vehicles it is essential to neutralize the effect of external disturbing couple which can be done by applying equal and opposite couple. Accordingly, to generate equal and opposite reactive couple it is essential to vary the magnitude and direction of velocity of precession. The active gyroscopic couple represents rate of change of angular momentum, and this couple must be applied to disc across the axis of spin to cause it to process in the horizontal plane. When the axis of spin process itself or is made to process the shaft on which the disc is mounted applies reactive gyroscopic couple. This reactive gyroscopic couple thus produced by the gyroscope is equal to the external disturbance but it is in opposite direction. Thus this couple neutralizes the effect of disturbance and stabilizes the object.

(Active couple) = - (Reactive couple)

III. WORKING

The model is powered by a power supply unit of 12V output. Once the motor starts rotating, the Mild steel disc fitted on the motor shaft starts to rotate and gradually gains speed. This rotation of the disc leads to the production of the gyroscopic effect thus, when the wheels lose their balance due to the active gyroscopic couple, a counter acting reactive gyroscopic couple is produced in the opposite direction due to gyroscopic effect, thus stabilizing the prototype model. This gyroscopic effect occurs on both left as well as right hand side. Thus, due to rotation of the gyroscope, a counter-acting reactive gyroscopic couple leads to the stabilization of the prototype. The motor and gimbal axle assembly is designed in such a way that it is too heavy. This means that

the center of gravity lies above the gimbal axle. So the motor and gyroscope assembly tries to attain the position such that the center of gravity of the core will move downwards. But at the same time the motor and gimbal assembly is arranged within the frame having bearing reaction at ends. So, the only possible way for motor to attain the stability is to either lean forward or backward. So, when the motor is started the body is about to fall on either side or also the motor assembly is leaning this causes the precession of spin axis. Due to this precession, according to right hand rule the reactive gyroscopic couple acts on the frame which nullifies the effect of the disturbing couple and thus stabilizes the vehicle. After few rotations and oscillations of motor, the motor and frame attains the stationary position and gyroscope is subjected to pure rolling motion about the spin axis.

IV. MODEL FABRICATION

The objective of this paper is to prove the fact that the a body can be balanced only on two parallel spin axis wheels in idle or running condition with the use of a mechanical gyroscope.

The gyroscopic principle can be successfully used for creation of a prototype of a two-wheeled vehicle, and thus observing gyroscopic phenomenon on the same.

The prototype was created using following parts:

1. Wooden Frame	2. Steel Base
3. 12V DC Motor	4. Mild steel disc
5. Flat head stud	6. Rubber Wheels
7. Nuts and bolts (M3, M5)	8. Hub
9. Circlips	10. Ball bearings

V. DESIGN CALCULATION

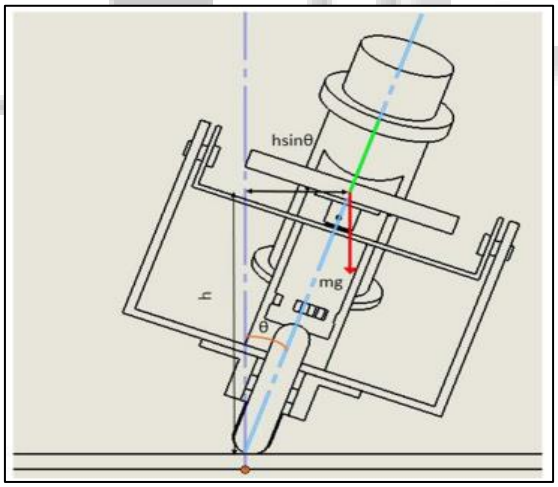

Fig. 2: Graphical Representation of Tilting of Bike

Basic formulas used in calculation:

A. *Active Couple (torque due to tilting of the body)*

Torque, $\tau = Fh\sin\theta$

Force, $F = mg$

Tilt distance $= h\sin\theta$

r = Radius of the disc

N = RPM

$I=(m*r^2)/2$

B. *Reactive Couple (torque due to gyroscopic effect)*

$\zeta=I*\omega_p*\omega_s$

Motor selected:-RS 775 Dc 24V motor

1) Specifications:

N=12000 rpm, ω_s=1256.64rad-s^{-1},(α=62.832 rad-s^{-2} assumed)

Power=200W

2) Gyroscopic Wheel Calculation:-

$P=\omega*\zeta_{motor}$

ζ_{motor}=0.159 N-m

$\zeta_{motor}=I*\alpha$

I=0.0025 kg-m^2

$I=(m*r^2)/2$

Assuming r =6 cm

m=1.5kg

Material = M.S steel (ρ=7.85 g-cm^3)

thickness, t=1.4cm

VI. CONSTRUCTION

The gyroscope disc is manufactured using CNC lathe and drilling operations. The steel frame used is bolted on the bottom steel base. Round edge wheels are fitted to the steel base at the bottom, the holes in the frame are drilled in order to fit the gimbal of the gyroscope assembly, the DC motor supported on a U bracket is placed on the gimbal. The only prerequisite for this setup to work is that the mass distribution, the mass should be dominant on the upper side (setup should be top heavy) of the gimbal. The center of gravity is thus just above the gimbal axis, stainless steel disc used as gyroscope are fitted to the shaft of the motor. The DC motor is bolted to the U-bracket due to which it remains intact with it and the shaft of the DC motor is fixed to a steel hub which has got holes drilled on its top flat surface to be used to finally fix the gyroscope disc by bolting it with the hub. The material used in making the gyroscope disc, hub, steel frame, and U-bracket is Mild Steel. To finally assemble the entire model, various sizes of nuts and bolts were used. One important design consideration that we made in this model is that the gyroscope disc should be freely suspended in the U-bracket connected to the steel frame. So for that, we used ball bearings and studs to make the angular movements and adjustments free and swift. The circlips are placed on the inner ends of the studs to avoid the studs to move out of the ball bearings, thus avoiding breakdown of the model during the running condition. The model has been made in such a way that the front wheel can move to take turns in order to change the direction of movement.

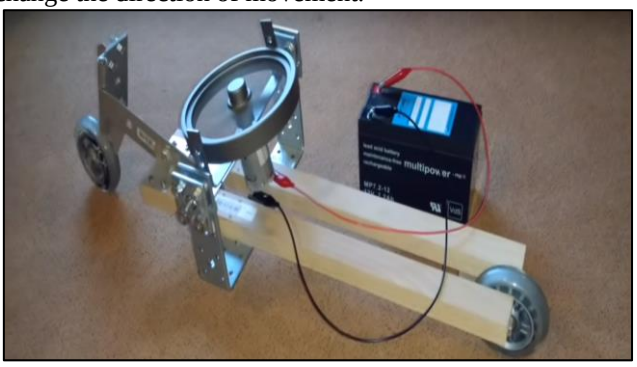

Fig. 3: Practical Model of the Balancing Bike

VII. CONCLUSIONS

After going through the research papers, case study and various calculations we come to a conclusion that self-balancing can be achieved using reaction wheel and gyroscopic wheel. Also that the incorporation with electric bike will be the best idea since the future of the transportation system is electric.

A. Advantages

1) Since the tilting of the bike can be avoided, the rides can be more comfortable.
2) Severe damage from falling can be avoided.
3) Using active gyroscope, the degree of turning can be controlled and henceforth autonomous driving can be initiated.

B. Disadvantages

1) Gyroscopic wheel consumes a lot of electric energy from the battery and hence might reduce the battery life of the bike.
2) During steep turnings, the gyroscopic wheel will oppose the turns since during turning tilt is required.

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