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A STUDY ON TWO WHEELER SELF BALANCING BIKE USING A GYROSCOPE

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ABSTRACT

In this day and age, automation has become more of a necessity than a luxury. Even after having several preventive safety measures, the use of two-wheelers leads to accidents. According to the survey most of them, happen because of imbalance or twowheelers going out of control. The need for a self-balancing system for two-wheelers is in high demand among the customers. This paper studied the gyroscopic method of a self-balancing bike. The gyroscopic effect is used in stabilizing systems for sectors like the Military's rocket guidance systems, aerospace, aeronautics industries, ships, etc. These sectors are using gyroscopes for years. We have incorporated this principle into our two-wheeler model. The factors which affect balancing are the center of mass of the system, mass distribution, acceleration, steering of the vehicle towards left or right, and most importantly gyroscopic effect.

Keywords: Gyroscope, Two-wheeler, Self-Balancing Bike (SBB), Stabilization

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1. INTRODUCTION

Despite the features and popularity of motorbike, it has lack safety and it is very risky. Therefore, motorbike accidents are fatal. An injury is a must while death is the more frequent scenario. In two-wheeler riders' body is exposed during ride time, and because of that riders get off the vehicle and gets exposed to impact with roadside elements[1]. In this scenario chance of damage is high. In the case of bike balancing, the rider must maintain proper bike motions. Motorcycle dynamics is the physics of the motion of bicycles and motorcycles and their components, due to the forces acting on them. Dynamics is a branch of classical mechanics, which in turn is a branch of physics. Bike motions of interest include balancing, steering, braking, accelerating, suspension activation, and vibration[2]. Among these balancing is the aspect that does not have any proper solution. So, to overcome this drawback of balancing, the self-stability of a two-wheeler is achieved by utilizing the principle of a gyroscope in a twowheeler. If it is a novice ride and has difficulty holding up a motorcycle when stopped at a light or when slowing down. Also, for any old-aged riders out there, having to hold up a 400-pound motorcycle might not be ideal. The bike goes unstable under certain conditions namely high speed, rider error, faulty components, slippery road, slipper clutch, and many other reasons. In the case of bikes, balancing is very important, particularly at low speed. By using our solution, those who are not able to balance the bike can easily ride it.

2. WORKING PRINCIPLE

Even if an external force is applied to the system the sensors deployed in the system, sense the force and develop a counter-force of similar magnitude but in opposite direction due to the presence of a gyroscopic disc used in the Self-Balanced Two Wheeler (SBTW) thus the vehicle does not lose it's balance even if the external force is applied to it. Accordingly, the main components were machined in-house and tested. The frame is fabricated as per the design so we can place the other assembly parts. Rubber wheels were attached at the front and rear ends of the frame. They are arranged in such a way that can enable free forward and backward motion. The assembly of the GIMBAL frame is made by using wood, to which the main driving motor and flywheel are fixed, which has a free axis of rotation and allows precession. A 12v DC battery is connected to the motor by connecting wires and was mounted on the base frame. A regulator which is connected between the battery and the motor is monitored and the RPMs were calculated. The gyroscope two-wheeler was fabricated and tested for stability. Calculations and analysis were carried out based on the output which was obtained from the model.

2.1. Design

The 2D model sketch is made according to the dimensions. With the help of a 2D sketch, a 3D model is made in Solid edge and Sketch up. The design was subjected to analysis and defects were scrutinized. Different stresses acting on the components were found. Accordingly, the main components were machined in-house and tested, so first, we designed the motor by using the standard dimensions of the 775 DC motor.

For the design of the shaft and flywheel, we selected the flywheel according to our model size In assembly, the motor shaft and flywheel are connected by the shaft which we have designed. We have designed the shaft and flywheel such as they are locked with each other. So when the motor shaft rotates the whole assembly of these parts rotates with it. After that, we designed the casing for the above assembly which includes Main Shaft and flywheel. Two ball bearings are selected and designed by using standard dimensions for casing and shaft. So that shaft can easily rotate freely in the casing. The material we used for the casing is wood. These all parts assembled. Then we designed metal chassis by using 1x1 inch square section columns. We designed a bearing holder. With the help of a bearing holder and two rods, the assembly and chassis are connected. Rubber wheels were attached at the front and rear ends of the chassis made with the help of a screw and bolt. They are arranged in such a way to enable free forward and backward motion as shown in Figure 1. A side view of the prototype for Self-Balancing Bike can be seen in Figure2. Further Table 1 depicts the various Components used in Self Balancing Bike.

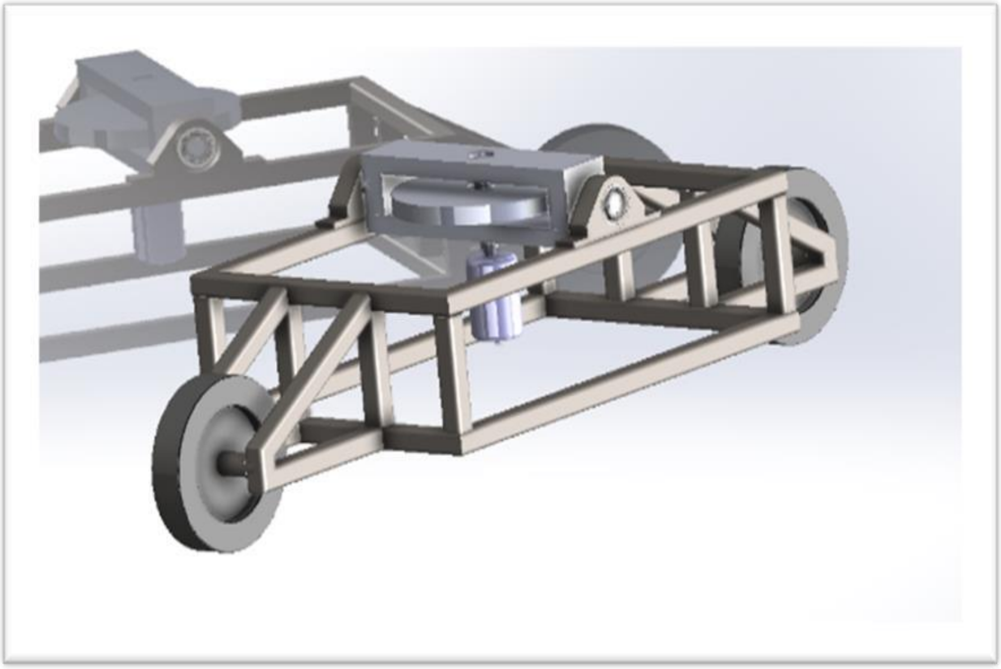


Figure 1 Isometric View of Self Balancing Bike

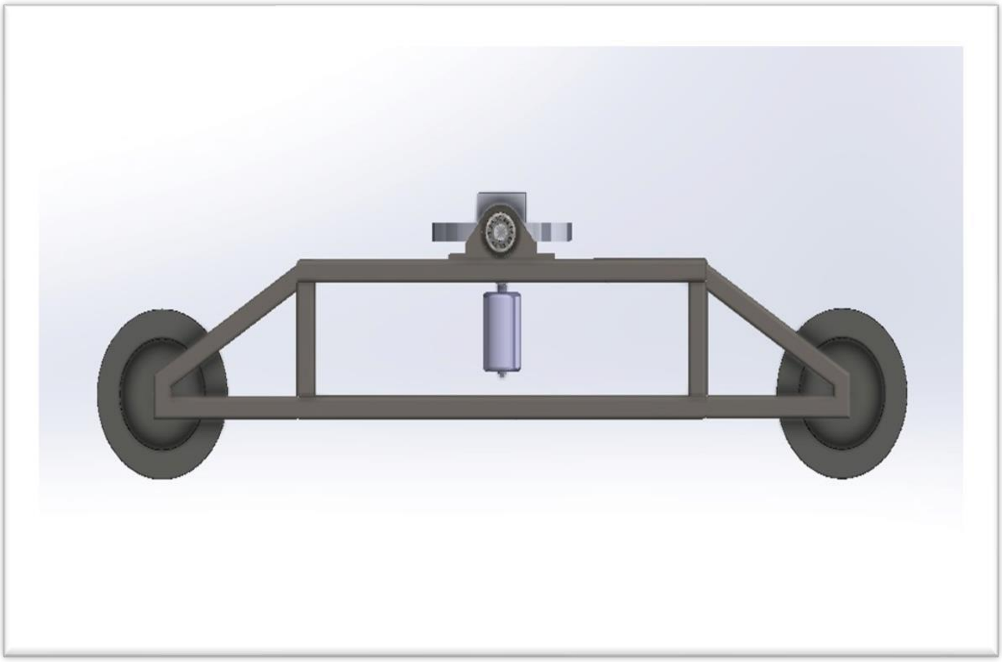
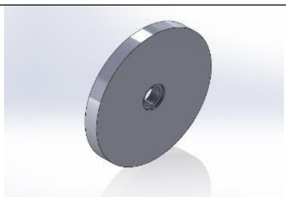
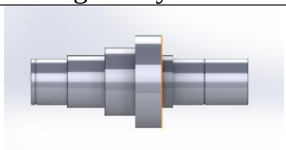
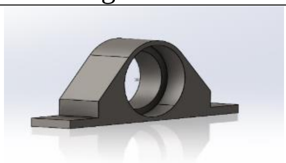
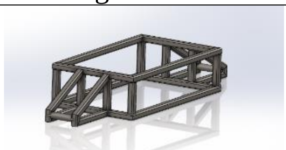
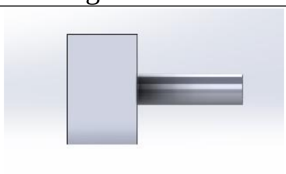
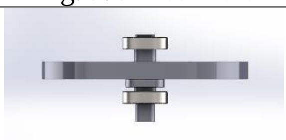


Figure 2 Side View of Self Balancing Bike

Table 1 Components of Self-Balancing Bike.

COMPONENTS	DESCRIPTION
 Fig.A. Flywheel	Flywheel - A disc-shaped solid piece of mild steel with a bore at its geometric center. This is an essential part of the CMG as its rotation helps to maintain the gyroscopic effect needed to keep the two-wheeler's balance.
 Fig.B.Shaft	Shaft - The material used for the shaft is mild steel it connects the motor to a flywheel. it helps the flywheel rotate with the motor
 Fig.C. Bearing Holder	A pillow block bearing or ball bearing holder. - The assembly consists of a mounting block that houses a bearing. It is mounted on the chassis to give a free one direction axis to the gimbal
 Fig.D. Bearing	A ball bearing - serves three main functions in the assembly while it facilitates motion: it carried the load for the shaft and flywheel, reduces friction between the gimbal and shaft, and positions moving parts like the shaft
 Fig.E.Wheel	Wheel – this is purchased from any shop or retailer in the market. this is regular wheel use to move chassis
 Fig.F. Chassis	Chassis - the vehicle's main support structure, also known as the 'Frame.' It bears all the stresses on the vehicle in both static and dynamic conditions. All assembly parts are on it
 Fig.G.Gimbal Part	Gimble side plate with rod - it consists of the gimble side plate and one end of the rod is connected with it and another end of the rod is connected with the bearing holder. It gives a free axis of rotation in a forward and backward direction
 Fig.H. Assembly of Flywheel, shaft, And bearing	This is the assembly of a flywheel, main shaft, and ball bearing. In this, the shaft and flywheel rotate together with the use of bearing
 Fig.I. Final Assembly	This is our final assembly of a Self-balancing bike (prototype)

2.2. Design Calculations

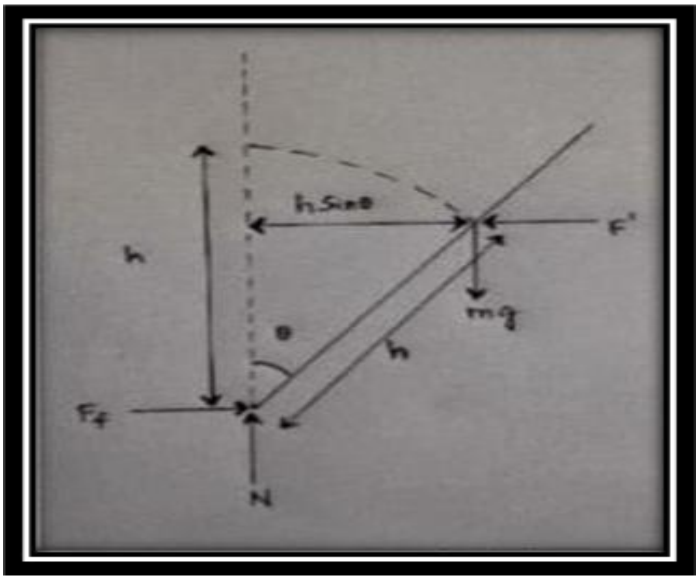


Figure 3 Forces acting on a self-balancing bike.

According to 'Fig 1', the mass of the system is 'm (kg)', and the distance of the center of mass ' m' from the ground is h(m). When the angle of tilt is $'\theta'$ then the torque induced 'r' is given by

$$\tau = m \times g \times h \times \sin(\theta)$$

And the Reactive Gyroscopic Torque (r') is given as

$$\tau' = m \times g \times h \times \sin(\theta)$$

(but in opposite direction) also

$$\tau' = I \times \omega \times \omega_p$$

Where I am the moment of the inertia of the disc, ω the angular speed of the disc, and ω_p the precession speed of the disc.

Now, we equate the above two equations,

$$m \times g \times h \times \sin(\theta) = I \times \omega \times \omega_p$$

Hence,

$$\omega_p = \frac{m \times g \times h \times \sin(\theta)}{I \times \omega}$$

This is called to be the maximum frictional force and be written as

$$F'_{max} = \mu \times N = \mu \times m \times g$$

Here,μ is the coefficient of friction, and N is the normal reaction force.

Hence, under limiting conditions,

$m \times g \times h \times sin(\theta) = F \times h \times \cos(\theta)$

Now, equating the above two equations the result is

$$m \times g \times h \times sin(\theta) = \mu \times m \times g \times h \times \cos(\theta)$$

$$\mu = tan\ \theta$$

Here $'\mu'$ is the coefficient of friction and ' θ' is the angle of tilt produced. Calculations for prototype:

Mass of DC motor = 0.4 kg
Mass of battery (12v) =1.5 kg
Mass of wheels (10") = 0.5 kg
Mass of Flywheel Disc = 4.5 kg
Mass of Frame =2.5 kg
Mass of chassis = 5 kg
Miscellaneous mass (Nuts, bolts, etc) = 1.1 kg
Total mass = 0.4+1.5+0.8+4.5+2.5+5+1.1 = 15.8 kg

Centre of mass from the ground (h):
= 34.6 cm
= 8.7 cm Z = 22 cm

$I = (1/2)M(R12 + R22)$

$I = 0.5 \times 5 \times (0.008^2+0.00852)$

$\therefore I = 16.1806 * 10^{-3}$ Kg-m^2.

Synchronous speed:

Ns = 6720 rpm (7000 * 0.96)

Speed of Disc :

N = 6500 rpm

Angular speed of disc,

$\omega = 680.67$ rad/sec.

The disc i.e flywheel is considered a part of CMG and is manufactured in-house.

∴The highest precision speed of the disc is

$$Wp = mghsin\boldsymbol{\theta}/Iw$$

$$= \frac{(8.8*9.8*0.24*\sin(15)}{0.01618*680.67}$$

$$Wp = 0.486 \text{ m/ sec}^2.$$

Highest Required Gyroscopic Torque:

$$\tau' = I\omega\omega p$$

$$= 0.01618*680.67*0.486$$

$$\tau' = 5 \text{ Kg m2/sec}^2.$$

2.3. Fabrication Process

The gyroscopic flywheel is manufactured using lathe and drilling operations. The Mild steel shaft is also manufactured using a lathe and drilling. To connect the shaft and flywheel, a key lock is used for the wooden casing which is made for the shaft and flywheel, two 6206 ball bearings are used so that the shaft can freely rotate in between the wooden casing. These two ball bearings are at the top and bottom sides of the shaft. The casing is the part of the gimbal, nuts, and bolts which are used to close the casing.

To fit the gimbal of the gyroscope assembly, the DC motor supported on a bracket is attached to the gimbal. The only pre-requisite for this setup to work is the mass distribution, the mass should be dominant on the upper side (setup should be heavy on the top) of the gimbal. The center of gravity is thus just above the gimbal axis, Mild steel flywheel is used as a gyroscope fitted to the shaft of the motor. The DC motor is bolted to the -bracket and the main shaft using an Allen key bolt due to which it remains intact with it and the shaft of the DC motor is fixed to a steel shaft which has a key lock to fix the gyroscope flywheel with the shaft. The steel frame is welded and all this assembly is assembled on that steel frame two bearing holders are fixed on the farm in the two balls bearing the assembly is assembled using two rods one side fixed with bearing and the other with casing or gimbal The material used in making the gyroscope flywheel, shaft, steel frame, and -the bracket is Mild Steel. One important design consideration that we made in this model is that the gyroscope flywheel should be freely suspended in the casing 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 the breakdown of the model during the running condition. Rubber wheels were attached at the front and rear end of the chassis made with the help of a screw and bolt. They are arranged in such a way to enable free forward and backward motion.

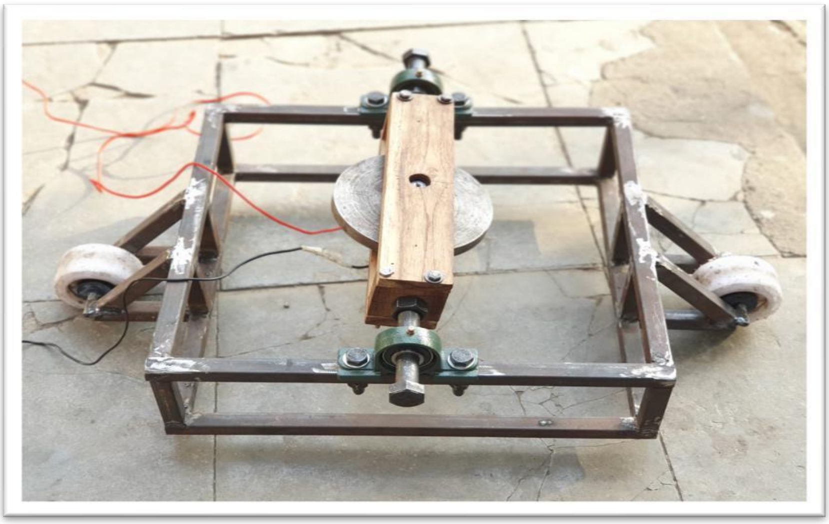


Figure 4

3. CONCLUSION

The gyroscopes which are conventionally used in airplanes and ships mainly for stabilization purposes can be effectively used for the self-stabilization of a two-wheeled vehicle, hence the prototype mentioned above was thus designed and fabricated to validate the same point. This research work presents the design and fabrication of the two-wheeled self-balancing vehicle which is capable of balancing with a simple design. Such a system can be much helpful for two-wheeled vehicles reducing accidents or unwanted falls and increasing safety for the rider.

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