ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 6, Issue 6, June 2019

Design and Fabrication of Self Balancing Mass Commuting Pod using Gyroscope

[1] Poorna R Prabhu, [2]Kevin John Mathew, [3]Namita A.R, [4]Soumya S Kumar, [5]Veena Sai G.J
[1][2][3][4][5] Department of Electronics and Communication, Mar Baselios College of Engineering and Technology, Mar Ivanios Vidhyanagar, Nalanchira, Trivandrum, Kerala – INDIA

Abstract: **The arising problem of global traffic on roads is mainly due to the ever increasing amount of vehicles being mass produced every year thus causing congestion and larger time gaps to commute between places. The proposed design is a large pod which are mounted on two legs that helps it travel over the traffic present on the road. The pod is self-balancing with the help of a gyroscope and a gimbal system. The gyroscope here acts as an actuator and not a sensor. When the vehicle tends to tilt from the vertical axis, an induced torque is applied to the gyroscope system and the vehicle will be corrected back to the axis due to the opposing gyroscopic reaction moment.**

We have designed and fabricated a system which will be able to efficiently transport the same amount of people travelling in a metro system without having to build the structures for it thus reducing costs. It is designed to run purely on solar energy with the help of solar panels on top of it. The traffic below will be unaffected as it requires a single rail path in between both the sides of the roads and also the space above the ground is highly unutilized. The legs which are contractible is realized using a scissor lift mechanism which can be replaced with a much more efficient hydraulic system for future uses. The added advantage of the system is that it can manually be run on custom paths and not just a pre-defined path making it useful in scenarios of extreme emergencies such as floods and also for ambulances and fire trucks built using this design.

Keywords - self-balancing, gyroscope, solar energy.

I. INTRODUCTION

In a rapid developing world, fast means of mass commuting is one of the growing demands. Increasing traffic levels especially in bigger cities is proving to be a big problem. The congestion created by the vehicles prove to be disastrous sometimes and the added factor of the pollution they create is a problem that needs to be addressed immediately. Need for larger systems which can accommodate more number of people has become a need which led to metros coming up in high tier cities. On the other hand the need for constructing the rail system for it to travel requires a long time and is not an economical solution. It provides lesser flexibility due to its design to travel only to specific places. The need for a design capable of carrying large masses of people efficiently without having to work on a path or structure for it to travel was very significant.

This paper presents a vehicle which is capable of commuting large number of passengers which runs above the ground balanced on two legs using the principle of gyroscopic stabilization. The vehicle can be seen as an economical, efficient and flexible way of travelling which is perfectly safe at the same time.

II. GYROSCOPE

A gyroscope is a device used in measuring and maintaining orientation of a system. It is a spinning wheel in which the axis of rotation or the spin axis is free to assume any possible orientation by itself. According to conservation of angular momentum, the orientation of the axis is unaffected by the tilting or rotation of the mounting. Considering a gyroscope with two gimbals, the outer gimbal, which is the gyroscope frame, is mounted so as to pivot about an axis in its own plane determined by the support. This outer gimbal possesses one degree of rotational freedom and its axis possesses none. The inner gimbal is mounted in the gyroscope frame (outer gimbal) so as to pivot about an axis in its own plane that is always perpendicular to the pivotal axis of the gyroscope frame (outer gimbal). This inner gimbal has two degrees of rotational freedom.

The axle of the spinning wheel defines the spin axis. The rotor is constrained to spin about an axis, which is always perpendicular to the axis of the inner gimbal. So the rotor possesses three degrees of rotational freedom and its axis possesses two. The wheel responds to a force applied to the input axis by a reaction force to the output axis.

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 6, Issue 6, June 2019

Gyroscopic Principles

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/Iω.

B. Gyroscopic Effect

In air planes and ships, there is always an external disturbing couple that is acting on the vehicle. It is essential to neutralize the effect of this couple to attain stability which can be done by applying equal and opposite couple. Accordingly, 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 precess in the horizontal plane. When the axis of spin precess itself or is made to precess 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. FABRICATION

The objective is to design a transport system which can self-balance itself using gyroscopic principles. The following materials were used to create the prototype:

1. Steel chassis
2. Scissor lift
3. Arduino Uno
4. Arduino Nano
5. Rubber wheels
6. Aluminium disc
7. 12 V DC motors
8. Steel brackets
9. Nuts and bolts
10. Ultrasonic sensor
11. Bluetooth module

A. Solar circuit for powering Arduino and flywheel

The following components were used for the fabrication of the solar powering circuit:

1. Solar Panel
2. DC to DC 5V USB module
3. Rechargeable battery
4. 1N914 diode

The rechargeable battery is used to store the charge generated by the solar panels. The power generated is used to drive the Arduino and the same can be used to rotate the flywheel motor as well. The design was created to be economical and efficient at the same time and solar energy proved to be the best source of power which can be fully utilized to power the vehicle.

B. Scissor lift mechanism

The scissor lift mechanism is used to lower the upper body which houses the commuters. This is done for two reasons, first so that the people will be able to get on and off the vehicle and second, to pass under obstacles such as bridges and transmission lines on its path. The movement is controlled with the help of an ultrasonic sensor which contracts the leg downward when an obstacle is detected and makes it go up after passing through. The scissor lift mechanism is implemented using two motors which rotate simultaneously to maintain the symmetry between both the legs during upward and downward movements. The scissor lift is fabricated by joining together metal strips in such a way that they open and close like a scissor enabling the design to raise and lower platform when an external force is given to it.

IV. CONSTRUCTION

A. The Gyroscope assembly

The disc which is used as gyroscope is manufactured using aluminium as the material. The gyroscope is allowed to rotate freely by suspending the assembly using a gimbal. Holes are drilled upon the chassis to which the U bracket is attached. A gimbal is fixed to the U bracket and suspends the gyroscope and the motor attached to it. A hole has to be put in the center for the DC motor to pass through and to be attached to the gyroscope disc. The mass distribution of the system has to be taken into account, that is the weight on top of the gimbal axis should be greater than that below it. This is realized by putting the gyroscope disc on top thus making the center of gravity just above the gimbal axis. The material that has been used in the manufacturing of the brackets and the chassis is mild steel. The gyroscopic disc should be freely suspended and this is done with the help of the U bracket which is attached to the steel chassis. The

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 6, Issue 6, June 2019

entire assembly was finally attached together using various sizes of nuts and bolts.

B. The platform movement

The movement of the platform upwards and downwards is controlled with the help of a scissor lift mechanism. The movement is controlled by an innovative design where a gear mechanism is replicated using a nut and bolt. The nut is attached to the lower rod of the scissor lift and the bolt is attached to the shaft of the DC motor. The bolt is made to pass through the nut and through a hole made in the center of the rod. As the motor rotates in one direction the scissor lift contracts and vice versa.

V. WORKING

The entire vehicle is powered by a 12V output which can be externally provided or from the solar panels. There are a total of seven motors- two motors each for the legs of the vehicle, two for the scissor lift mechanism and one for spinning the gyroscope. The rotation of the gyroscope produces a 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 which will be the stabilizing factor of the vehicle. The top heavy design of the motor and the gimbal axis has helped in making the center of gravity lie above the gimbal axis and this leads to the motor and the gyroscope assembly trying to rearrange itself in such a way that the center of gravity will move downwards. But the design is done in such a way that the motor and the assembly is fixed to the bracket and will not be able to move downwards. This is only possible by the movement of the motor leaning forward and backward to attain stability. There is a chance that the body can fall onto either side when the weight on either side increases or a large enough force acts on the vehicle to displace it and the movement of the motor leaning forward and backward together causes a precession in the spin axis. This results in the gyroscopic couple acting on the side frame and it nullifies this couple and stabilizes the vehicle. Within a short span of time, the entire assembly will gain stability again even after being displaced thus showing that the vehicle will remain standing as long as it is powered.

VI. EXPREIMENTS AND RESULTS

To study the gyroscopic effect,
The basic formulas that needs to be used are,

Moment of Inertia = $\frac{mr^2}{2}$

Angular Momentum, $I\omega = \frac{mr^2\pi n}{60}$

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

Force, F= mg

Tilt distance = $h\sin\theta$

m= Mass of the disc = 0.8 kg

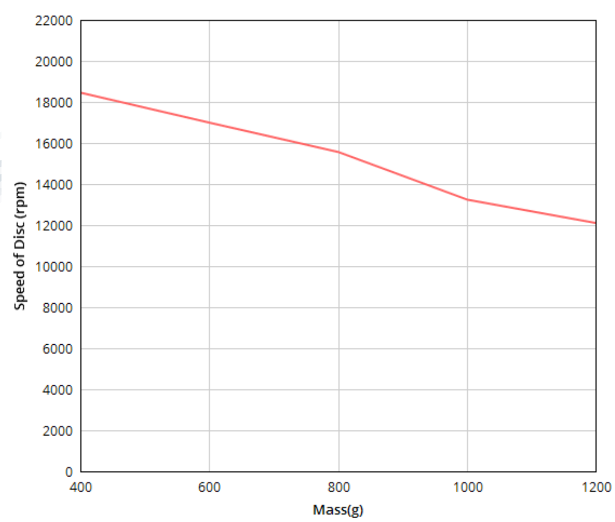
r= radius of the disc = 32.5 mm

n= speed of disc (rpm)

h=1 m

Table 1
Mass vs Speed table

Serial No.	Mass(in g)	Speed of rotation
1	1200	12100
2	1000	13240
3	800	15560
4	600	16990
5	400	18450



Graph 1 : Mass(g) vs Speed of disc(rpm)

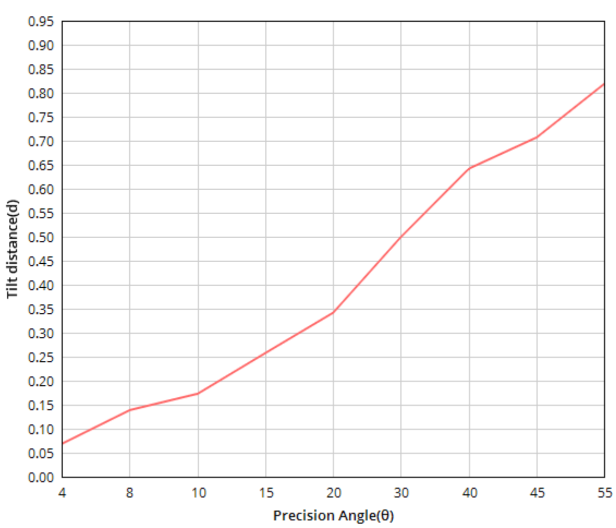
This graph shows the impact of the mass of the disc on the speed of the disc. It is clear from the graph that when the mass increases, the speed decreases correspondingly.

ISSN (Online) 2394-6849

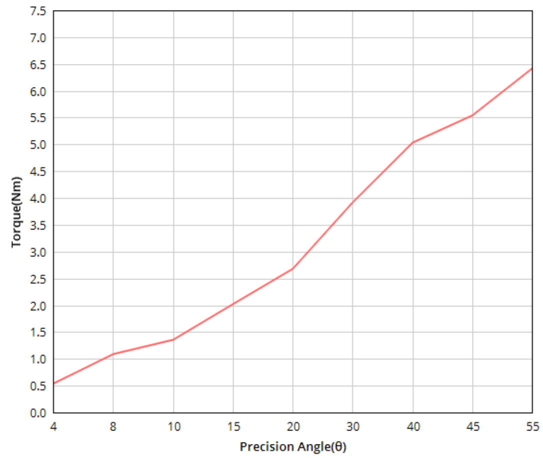
International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 6, Issue 6, June 2019

Table 2
Changes of Tilt Distance and Torque with respect to Precession Angle

Serial No.	Precision angle(θ)	Tilt distance(d)	Torque(Nm)
1	4	0.069	0.540
2	8	0.139	1.089
3	10	0.173	1.356
4	15	0.258	2.022
5	20	0.342	2.681
6	30	0.5	3.92
7	40	0.642	5.033
8	45	0.707	5.542
9	55	0.819	6.420



Graph 2: Precision angle(θ) vs Tilt distance(d)



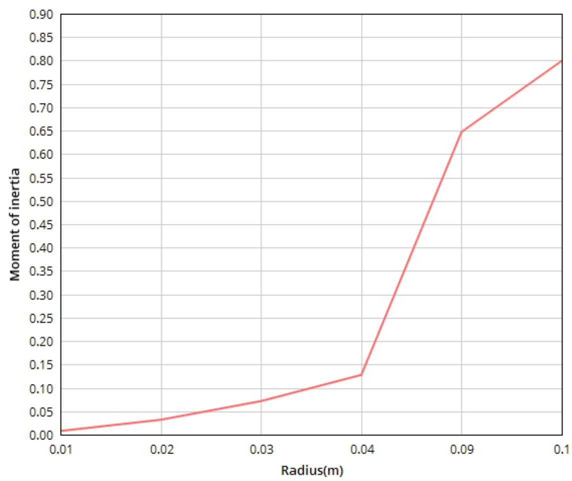
Graph 3: Precision angle(θ) vs Torque(Nm)

The graph depicted above shows the relation between Precession angle and Tilt distance of the gyroscope. Here, if the angle of precession axis varies, the distance of the precession axis from the normal varies accordingly. As a result, with the increase in precession angle, the tilt distance also increases.

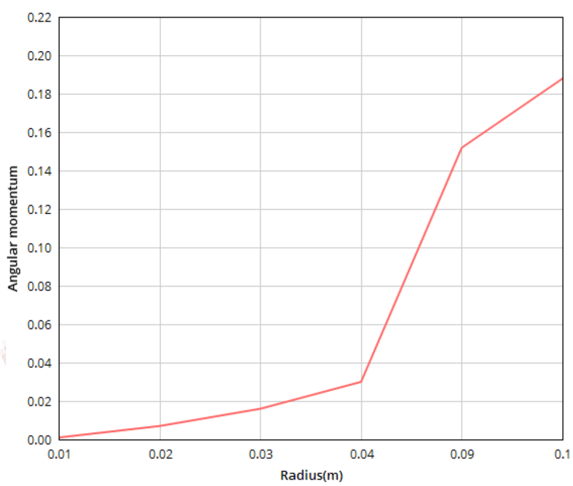
Other graph is the representation of the results by changing the Precession angle in order to obtain corresponding values of Torque to the change in the values of Precession angle. When the Precession angle increases, a change in the value of Torque generated by the gyroscope. From the above graph, increasing values of Precession angle leads to increase in the Torque generated by the gyroscope.

Table 3
Changes of moment of inertia and angular momentum with respect to radius

Serial No.	Radius(m)	Moment of inertia(kgm^2)	Angular momentum(kgm^2/s)
1	0.01	0.00008	0.0001
2	0.02	0.00032	0.0007
3	0.03	0.00072	0.0016
4	0.04	0.00128	0.0030
5	0.09	0.00648	0.0152
6	0.1	0.008	0.0188



Graph 4: Radius(m) vs Moment of Inertia



Graph 5: Radius(m) vs Angular Momentum

The graph gives the clear idea that when there is any increase in the radius of the gyro disc, the Moment of Inertia (MI) produced by the gyroscope also increases. So, varying the radius of the gyro disc, the Moment of Inertia (MI) also varies accordingly. Graph 2 shows the relation between the radius of the gyro disc and the Angular Momentum produced by the gyroscope. Here, increasing the radius of the gyro disc, the Angular Momentum also gets increased in response to the varying radius and vice versa which means that radius is a varying factor to obtain varying Angular Momentum values for the gyroscope.

APPLICATIONS

The above gyroscopic stabilization system can be implemented in a wide range of applications in day to day uses especially in cases of emergency transports such as fire trucks and ambulances that need to travel long distances in a very short span of time and also in cities where mass commuting is a very big problem. The feasibility of such a design allows it to be used in other cases such as long distance transport which can easily transport commuters across cities therefore giving a challenging option against present available options such as buses and trains, also being economic at the same time.

CONCLUSION

This paper presents the design and fabrication of a self-balancing mass commuting vehicle which is capable of balancing itself under application of extreme external forces and large amounts of loads. The vehicle is eco-friendly and is capable of replacing existing structures like metros which needs huge amount of money to be built and power to run on. It utilizes the self balancing capability to provide various no of applications thus making this system an efficient and economic design to implement.

REFERENCES

[1] Min S. Ha , Seul Jung, “Balancing control application using gyroscopic effect to a hand-carried one-wheel cart”, 2015 IEEE International Conference on Advanced Intelligent Mechatronics (AIM), July. 2015

[2] D. M. Malyutin, “Miniature gyroscopic orientation system for unmanned aerial vehicle”, 2018 25th Saint Petersburg International Conference on Integrated Navigation Systems (ICINS), May. 2018

[3] Karthik, Ashraf, Asif Mustafa Baig And Akshay Rao, “Self Balancing Personal Transpoter” 4th Student Conference on Research and Development, pp. 180-183, June.2006.

[4] Pallav Gogoi, Manish Nat, Bumi Trueman Doley, Abhijit Boruah, Hirok Jan Barman, “Design and Fabrication of Self Balancing Two Wheeler Vehicle Using Gyroscope”, International Journal of Engineering and Technology (IJET), Vol 9 No 3 July.2017

[5] Stephen C. Spry and Anouck R. Girard, “Gyroscopic Stabilization of Unstable Vehicles: Configurations, Dynamics, and Control”, March 31, 2008

[6] Simos Evangelou “THE CONTROL AND STABILITY ANALYSIS OF TWO WHEELED ROAD VEHICLES” University of London, Electrical and Electronic Engineering Imperial College London September 2003