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Design and Fabrication of Self Balancing Bike Using Gyroscopic Effect

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ABSTRACT:
Balancing a two-wheeled vehicle plays an important role in all transportation system and it is always been a challenging task. The study of kinematics concept helps to understand the subject of Balancing of objects or bodies under static and dynamic condition. The motion dynamics of a two wheeler vehicle is very different from other vehicles. So many experiments and calculations conclude that a two wheeler vehicle stays upright when it is steered to maintain its center of mass over its wheels. Either the rider steers to balance the vehicle or the vehicle itself balances above a definite velocity. Factors such as gyroscopic effect, centre of mass, mass distribution contribute in self-stability of bicycle. The dynamic stabilization of a two-wheeled vehicle requires that a torque acting on the vehicle naturally be neutralized by a torque produced within the vehicle by a gyroscope.
We design and fabricated a self balancing bike with gyroscopic effect .The construction of this bike includes design calculations, modeling in CATIA, and a fabrication process in which accelerometer sensor is used to stabilize vehicle . Arduino and controller combination is used to give continuously commands to vehicle.

Keywords : Kinematics, Sensor, Controller, Static, Dynamic

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I. INTRODUCTION

In the present generation motor bike is one of the good choice to reach a destination in a short time with in a economic level of the human being. There are so many advanced features in bikes are invented to avoid accidents . When the man got an accident on road side elements there was a more probability to loss his/her life. Most of time rider losses control to get stability when he rides the bike. To avoid all these limitations of the bike a self balancing bike can helpful in the sense of safety, vehicle damage. The self-balancing bikes works on the principle of “Gyroscopic effect”. And it’s applications had been using in airplanes and ships from many decades. In case of bikes when it tilts left or right, it induces a reactive Gyroscopic couple in the opposite direction. So that vehicle balances by this gyroscopic effect. In previous research work to balance two wheeler they used principle of pendulum, force sensors and give power by electricity. In our project which accelerometer sensor is used to stabilize vehicle. Arduino and controller combination is used to give instructions time to time for continuous movement of the vehicle.

II.LITERATURE REVIEW

Self balancing bike is one of the most awaiting technologies the world right now. Some of companies like Honda, Harley Davidson had already shown their success in this concept. Recently Harley Davidson

Company files patent for the self balancing technology. They said gyroscopes in the vehicle disengage beyond 3mph (4.8kph) in order to turn a vehicle at high speeds where gyroscope effect will create automatically. So we don't need to operate gyroscopes specially; gyroscopes wheels in the vehicle rotate with the electric motor which spins between 10000-20000 r.p.m.The whole system will be enclosed with in Harley’s Tour pak top case. You can remove this case when you no longer need if much like training wheels on a bicycle.

Patents are many for self balancing bikes because different companies use different technology some of them uses servo motor and some people uses D.C motor. Some people uses only gyro sensor and some people uses both gyro and accelerometer sensor.

Author [1] has designed a two wheeler self balancing which aims to balance the two wheeler against any impact and in a static condition they used two heavy rotation disks to compensate felt of two wheeler.

Author [2] stated that "there are several ways in order to design an efficient self balancing bicycle by using control moment gyroscope and mass balancing steering control and reaction wheel usage of CMG gives great effect".

Author [3] stated that "the vehicle is powered by a battery source. The motor DC 24v,250w (or) 500w,high torque whose speed will be controlled by a custom designed circuit uses sensor like IMU, which mounts accelerometer and gyroscope is used to monitor the posture of the person ".

Author [4] stated that "the rotation of the disc leads to the production of gyroscopic effect when the vehicle loses there balance reactive gyroscopic couple maintains stability".

Author [5] stated that "CGM and PD controller has short response time to balance and an effective activator as an torque amplifying device. Various simulations done and programmed in lab view results showed that PID controller not is unable to control and unstable".

III. MAIN COMPONENTS

Main components that are used in the proposed model are

1) 12-Volt Motor
2) Flywheel
3) L298N Motor Controller
4) Gyroscopic Sensor
5) UNO Arduino

3.1 12-Volt Motor:

A DC Motor of 4-12 volts capacity is used and is used as power source to the gyroscopic discs. They are placed with the help of U-Shaped frame

3.2 Flywheel:

The flywheel is used to produce the gyroscopic effect. The flywheel is attached to the motor whose sole purpose is to rotate the flywheel as per the required gyroscopic effect

3.3 L298N Motor Controller:

Motor controller is a intermediate device acts between the motors, batteries, robots microcontroller. Motor torque depends on the supplied current.

There are only 3types of motor controllers they are

1) Brushed stepped motor controller.
2) Servo motor controller.
3) Stepper motor controller.

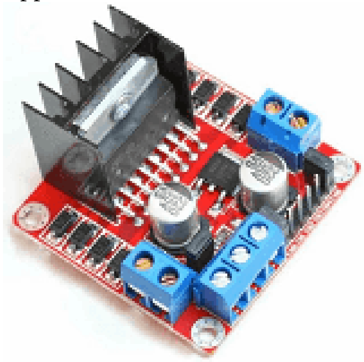


Fig 3.1: Motor Controller

3.4 Accelerometer Sensor:

An Accelerometer is a TRANSDUCER that is used to measure the physical or measurable acceleration that is made by an object. Co-ordinate acceleration cannot be measured using this device. An accelerometer is an electro-mechanical device that is used to measure the specific force of an object, a force obtained due to the phenomenon of weight exerted by an object that is kept in the frame of reference of the accelerometer. In the case of static acceleration, the device is mainly used to find the degrees at which an object is tilted with respect to the ground. In dynamic acceleration, the movement of the object can be foreseen.

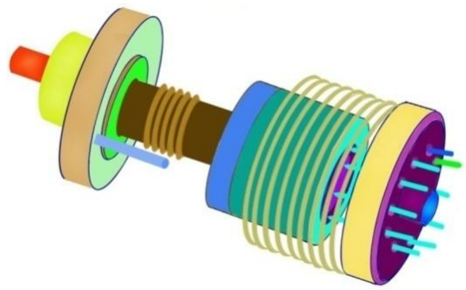


Fig 3.2: Accelerometer sensor

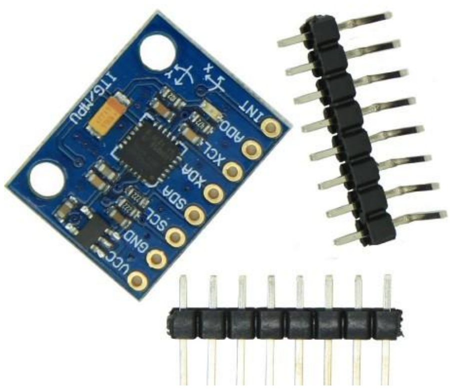


Fig 3.3: Axis Accelerometer

3.5 Arduino:

Aurdino is an open-source electronics platform based on easy-to-use hardware and software. Of Aurdino boards are able to read inputs – light on a sensor, a finger on a button, or a Twitter message – and turn it into an output – activating a motor, turning on an LED, publishing something online.

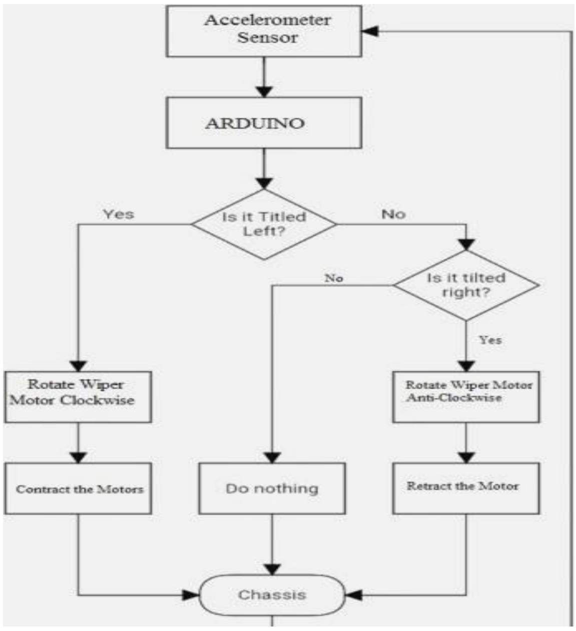
The Ardino board is connected to a computer via USB, where it connects with the Arduino development environment (IDE). The user writes the Arduino code in the IDE, sssand then uploads it to the microcontroller which executes the code, interacting with inputs and outputs such as sensors, motors, and lights.

Fig 3.4: Arduino

IV. WORKING PROCESS OF MODEL

The sensors like accelerometer, gyro sensors are fitted to the chassis of the vehicle, which detects the correct position of the vehicle. Whenever the body tilts from its vertical position sensors reads the acceleration, angle of the body accordingly to that data torque generates. The output of sensor sent to arduino. Arduino cheeks in which direction the body tilted according to that instructions will pass out to the controller. The instruction for tilting left is to rotate the motor shaft in clockwise, if a vice versa. Controller controls the motor unit to maintain its r.p.m by taking power supply from battery. Electric motors have the greatest torque at start.

There is a wheel or disk connected to a motor which is mounted on a gimble. When the vehicle is unstable gimble movement changes. In order to get over position back Hub-motor will create gyroscopic effect, there by gimbles again come to its original position.



V. DESIGN OF MODEL:

Components	Dimensions(cm)	Diameter(mm)	voltage capacity	Weight (gms)
Chasiss base frame	50x18x3	-------	-------	400
Upper frame	25x18x25	-------	-------	205
Fly wheel		20	-------	400
Battery	15x6x8	-------	12V	-------
Wheels		26	-------	1170
12 Volt D.C. motor	-------			350

Table: 5.1 Specifications of components

5.1 Design Calculations:
Mass of the system M = 2.75 kg
Distance/Location of center of mass (m) from the ground

h = 0.17 (m)
When angle of Tilt = 15^0
Then Torque induced = m g h sin θ
$=2.75*9.81*0.17*\sin 15^0$
$= 2.98$ kg $-m^2/s^2$

∴ Reactive Gyroscopic Torque = m g h sin θ (opposite Direction)

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

$\Rightarrow m\,g\,h\sin\theta = I\,\omega\,\omega_p$

$\Rightarrow \omega_p = m\,g\,h\sin\theta / I\,\omega$

τ'=Reactive gyroscopic couple
I = Moment of inertia of disc

ω= Angular Velocity
ω_p= Precessional Angular Velocity
Thus,
Centre of mass from the ground,

h= 0.17 m
Moment of inertia of the disc,

$I=mr^2/2$

$=0.4*0.1*0.1 /2$ kg-m^2
Speed of Disc,

N =200rpm
Angular Speed of Disc, ω= 2*π*N/60 rad/sec

= 2* π *200/60

= 21.9 rad/sec
Since We Know That
$mghsin\theta = I\omega\omega_p$
The vehicle is designed for the maximum tilt angle= 1
Therefore the highest precision speed of the disc is ω_p= mghsinθ/Iω=2.98/(0.002*10.47)rad/sec
=67.91rad/sec
So Highest Required Gyroscopic Torque τ'= $I\omega\omega_p$
= 21.94*67.91*0.002kg–m^2/sec^2
= 2.97 kg-m^2/sec^2

5.1.1 Design of wheel:

Radius of wheel (R) = 13 cm
Centre of hole = 10 mm
Width of hub (B) = 60 cm
Load (P) =2.8 Kg
Thickness of Hub (T)=3 mm
For tensile strength:
We know that
Tensile stress = force/area
=F/(2*π*r*t*B)

=2.8*9.81/(2*π*5*3*60)

=4.86*10^{-3}MPA

=4.86 KPA
Maximum allowable Tensile strength of poly ethylene = 15 M.P.A
Since 4.86 < 15 MPA (So design of wheel is safe)
For bending strength of chasis:
σ_b =MY/I
= (6.6*250-1.95*250)*30/2022
=17 MPA
Where I= Moment of inertia = 2022 mm^4
Y= Length from the ground
M= Bending moment
Maximum allowable bending stess of aluminium = 300 MPA
17 MPA<300 MPA(So the design is safe.)

5.1.2 Design of upper frame column:
Number of columns = 4
Cross – sectional area of frame = 189 mm^2
compressive strength(σ_c) = force/area
= (350+400+50)*10^{-3}*9.81/189
= 0.41/4 MPA
= 0.1025 MPA= 102.5 KPA
The maximum allowable tensile strength of aluminium = 300 MPA
Since 102.5 KPA < 300 MPA(So the design is safe.)

5.1.3 Design of motor shaft:
Motor specifications:
Rated speed (N) = 300 RPM
Power (P) = 60 W
We know that
Power (P) = 2*π*N*T/60
60 = 2*π*300*T/60
Torque (T) = 1.9 N-M
We know that
Torque (T) = π/16*(τ*d^3)
Shear stress (τ) = 1.9*16*/(π*6^3)
= 0.044 MPA
= 44 KPA
Shear stress = 0.6*Tensile strength of Al = 0.6*400
=240 MPA
Since 44 KPA < 240 MPA
So the shaft design is safe.
5.1.4. Design of Gimble Arm
Number of arms = 2
Load (P) = load of motor + load of disc
= (350+450)*9.81*10^{-3}
=8.8 N
we know that
σ_c= load/area
= 8.8/(30*3*2)
= 0.097 MPA
= 0.048 MPA
= 48 KPA
The maximum allowable compression strength is σ_c = 400 MP
Since 48 KPA < 400 MPA
So the design of arm is safe.

VI. MODELING OF VEHICLE:

The modeling of vehicle is done in CATIA software with v5 version. Using CATIA individual parts are modeled using component dimensions and finally all the parts are assembled.

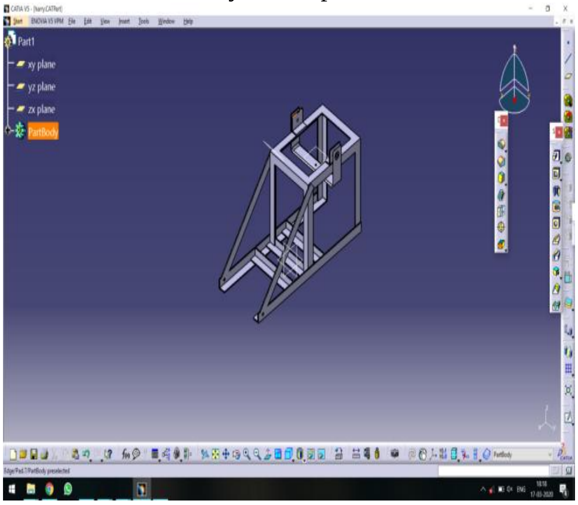


Fig: 6.1 Main frame modeling

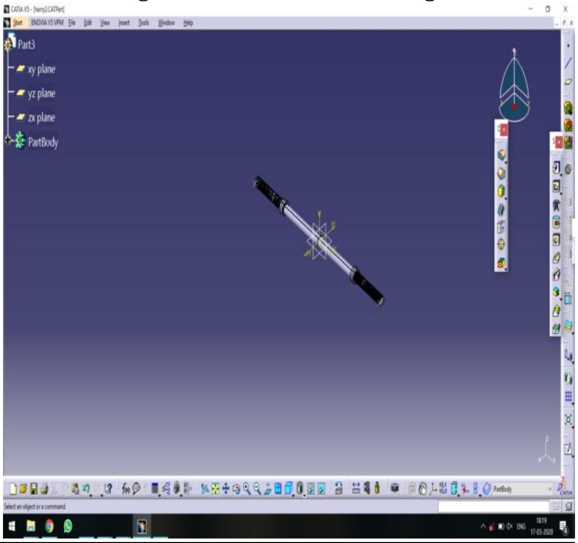


Fig. 6.2 Axle modeling

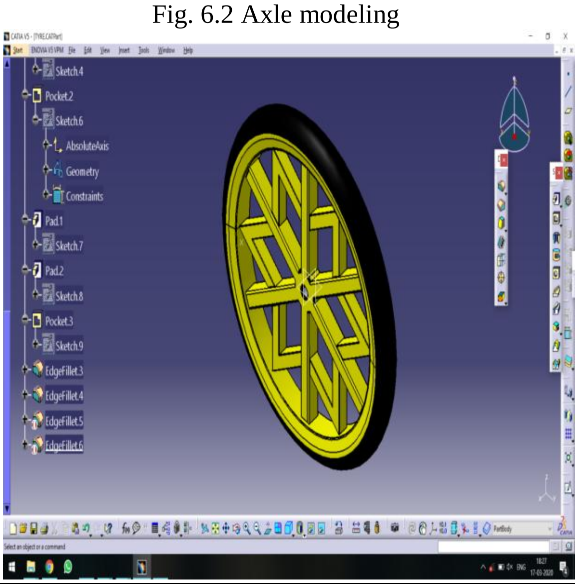


Fig. 6.3 Wheel modeling

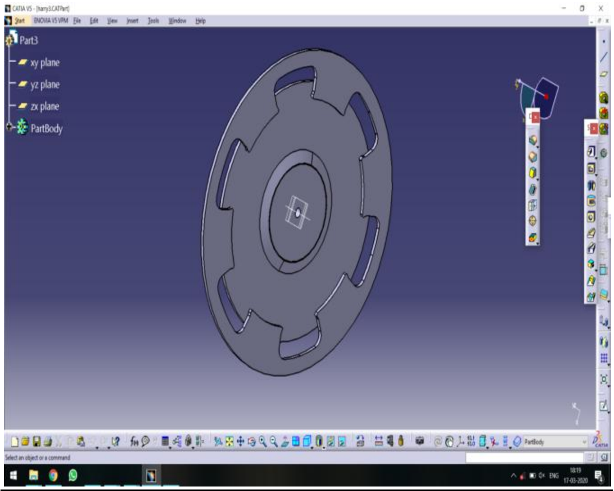


Fig. 6.4 Circular Disc modeling

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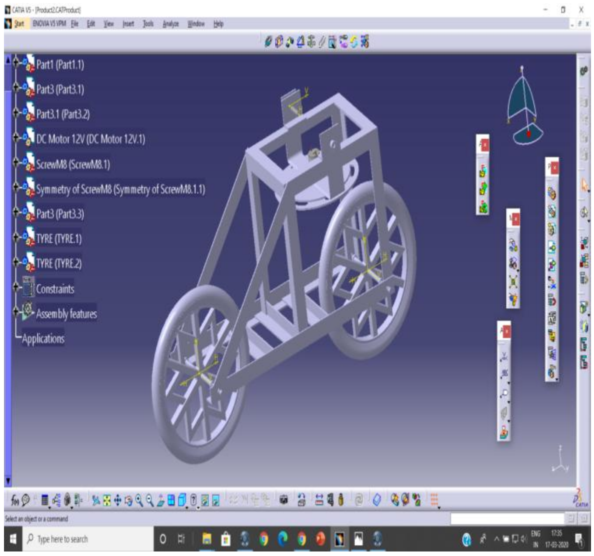

Fig. 6.5 Assembled of Parts of vehicle

VII. FABRICATION OF SELF BALANCED VEHICLE:

In fabrication process Aluminium L-angulers are taken for the whole frame, and for u frame gimble we used flats .Various electronic kit is kept on the base frame for gyroscopic effect .Finally wheels and remaining small aprts are attached to complete fabrication of self balanced bike..

Fig:6.1 Assmebling of indivisual parts of bike self balanced bike

Fig:6.1 Fabricated self balanced bike

VIII. CONCLUSIONS

A self-stabilizing gyroscopic two wheeler was designed and fabricated. The model is able to stabilize itself under 2500rpm supplied by the DC Motor to the flywheel. In this project suitable frameworks were taken into account. The most suitable frame is that of a single axis on the ends of which are the wheels and perpendicular to this is the spin of the flywheel. This was found to be the most optimum design in terms of vibration and effectiveness. The design of the gyroscopic stabilized two-wheeler was made .The area where the most amount of stress developed was found to be around the axis of rotation of the flywheel. It was also found that the flywheel mounted perpendicular to the axis of rotation of the moving wheels provides the required gyroscopic action to maintain a plane of balance. Experimental results have shown that when the flywheel achieves a speed of 2500 rpm. The theoretical calculation of the speed and experimental results were compared and studied. The experimental results were found to be in close proximity to that of the theoretical calculations. The gyroscopic effect created by the flywheel rotating at 2500 rpm or above generates enough angular momentum to stabilize the two wheeler prototype.

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