Design and Fabrication of Self Balancing Bike

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Abstract-This paper reports to design and build a bike prototype that is capable of driving and balancing without a rider. The Self Balancing bike will employ a control system to keep itself from falling over while in motion and be propelled by a motor. The goal of this project was to build a two inline-wheel bicycle prototype capable of balancing itself using a flywheel. This bike is able to drive and also come to a complete stop without losing its balance. In order to maintain balancing, the sensor read input to detect tilt angle and correctly reacts to maintain a steady vertical position. Sensor data is fed into a control system which outputs a balancing torque to a motor spinning the flywheel. The requirements include that the bike should be capable of accelerating, driving in a straight line and stopping without falling.

Keywords-Accelerometer, Balanced bike, Balancing control, Flywheel, Gyroscopic effect, Microcontroller, Sensor

1 INTRODUCTION

The deployment of electric vehicles in vast quantity can viewed as a carbon free transportation sector. As because of pollution the environment is also getting weaker and hence the quality of life also affects dramatically. The majority of the carbon emission is due to the fossil fuel vehicles. There is so much innovation when it comes to the four or three-wheeler market, as most of the cars are now electric and come with lots of different feature when it comes to the human safety. In the other hand because of lack of innovation in manufacturing of the two-wheel motorcycle we are still lacking behind when it comes to rider safety. The solution here is making a bike which can balance itself using the principle of gyroscope so that the rider not have to worry about falling because of lack of balance over the bike. The idea here is to make a bike which can balance itself without human interaction. As the bike is balance itself with the help of gyroscope it is also safe for the people which have certain disability.

Bicycle Physical Dynamics have been studied by Scientists, Engineers and Mathematicians. Self-Stability Balancing existence on controlling a moving Bicycle has not been extensively researched or achieved satisfactorily. For Transportation and recreation Bicycles have been a popular form over a century. Focused on various methods and algorithms to Self-Balance Bicycle with various disturbances applied on it. Our findings will be related to any application involving the control of a two wheeled aligned vehicle. It is based on development of self-balancing two- wheel bicycle by using various mechanisms and control algorithms for stability purpose. These Techniques will assist the future development of stability controllers for bicycles.

2. BACKGROUND

A bicycle is inherently unstable and without appropriate control, it is uncontrollable and cannot be balanced. There are several different methods for balancing of robot bicycles, such as the use of gyroscopic stabilization by Beznos et al. in 1998 Gallaspy in 1999, moving. of the Centre Of Gravity (COG) or mass balancing by Lee and Ham in 2002, and steering control by Tanaka and Murakami in 2004. A very well-known self-balancing robot bicycle, Murata Boy, was developed by Murata in 2005. Murata Boy uses a reaction wheel inside the robot as a torque generator, as an actuator to balance the bicycle. The reaction wheel consists of a spinning rotor, whose spin rate is nominally zero. Its spin axisis fixed to the bicycle, and its speed is increased or decreased to generate reaction torque around the spin axis. Reaction wheels are the simplest and least expensive of all momentum-exchange actuators. Its advantages are low cost, simplicity, and the absence of ground reaction. Itsdisadvantages are that it consumes more energy and cannot produce large amounts of torque.In another approach proposed by Gallaspy the bicycle can be balanced by controlling the torque exerted on the steering handlebar. Based on the amount of roll, a controller controls the amount of torque applied to the handlebar to balance the bicycle. Advantages of such a system include low mass and low energy consumption. Disadvantagesinclude the ground reaction force it requires andits lack of robustness against large roll disturbance.

3. OBJECTIVE

- To develop a simplest, safe & efficient Self-stabilizing two-wheeler.
- To stabilize the unstable system to maintain upright position by incorporating gyroscope sensors.
- To reduce the cost & weight of the system.

4. DESCRIPTION OF SYSTEM

In order to meet the design requirements, potential designs for controlling the balance of the bicycle were developed and will be explained in this section. The design is described below with particular attention given to how well this meet the selection criteria physical complexity, power requirements, programming code complexity, ease of turning/steering, math complexity, deviation from a straight line, cost, and closeness to resembling a bicycle.

The level of difficulty is related to the number of motors and sensors required, the reaction time required, and starting and stopping. Finally, power requirements include the battery necessary to provide the system with 10 continuous minutes of power supply (the original power supply requirement; it has now been changed to 5 minutes). The required battery is dependent on the weight of the model, number of motors needed for that design, and the torque demanded of the motor(s) for the control system.

The flywheel design employs a flywheel which rotates about an axis parallel to the bicycle's frame. The flywheel design has several advantages. This design is very stable the bicycle can balance even in a stationary position. The mathematical model of this system is the least complex of the considered designs. Due to the simplicity of the design, the model would most likely be the closest to reality of the design. As a result of the relative math simplicity and the ease of starting and stopping, the controller would be relatively straight forward to implement. This design would also allow the bicycle to travel in a relatively straight line with only small deviations.

4.1. Control Overview

The control of the balancing bike is controlled by a microcontroller and propulsion remotely controlled by an operator.

The ATmega328P (the selected microcontroller) reads the output of the accelerometer and the gyroscope via the 12-bit, and interprets the resulting values as a measurement of the bicycle's tilt angle. The measured angle is implemented into a PID algorithm, and outputs a corresponding voltage to the motor controller. The motor controller then outputs a voltage to the DC motor, which is geared down, and ultimately actuates the flywheel. A torque is exerted on the flywheel, and a reaction torque is exerted on the bicycle.

Fig 1 Microcontrollers

4.2 How Balancing Work

- When the GYROSCOPE MODULE receives the constant distance (same) the micro controller will rotate the fly wheel at slow speed and balance the bicycle.
- When the GYROSCOPE MODULE receives the different distance(Not same) the micro controller will rotate the fly wheel at high

speed clockwise or anticlockwise and balance the bicycle (gravity motion).

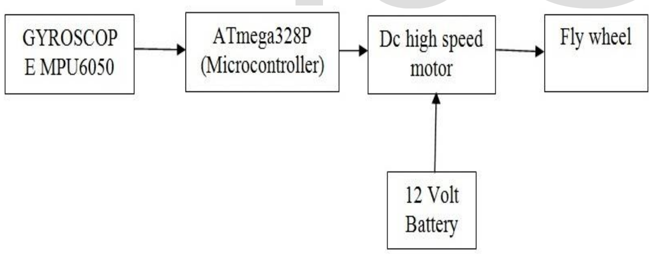
The block diagram of balancing is shown in Fig 2 below.

Fig 2 Block diagram of balancing of bicycle

4.3. Gyroscope Sensor

To measure the bicycle's tilt angle, it was decided to use an accelerometer and a gyroscope, and to combine them using a complimentary filter. Integrating these two sensors proves useful when calculating the bicycle's tilt angle. Accelerometers may be used to measure the angle with respect to gravity directly, but they are highly susceptible to noise.

Gyros are less susceptible to noise, but they meas-



ure angular velocity. As a result, the gyro output must be integrated in order to obtain a measurement of angular position. This integration yields an error known as drift, a drawback of the gyro. Integrating both sensors allows one to easily combine the output of each sensor in order to obtain a more accurate angle reading. This is accomplished through the implementation of a filter, which combines the advantages of each sensor and eliminates the drawbacks of each sensor.

Fig 3 Gyroscope Sensor

5. CALCULATIONS

5.1Design Calculations of Stepper Motor

DC Motor Speed (N) = 1250rpm

Voltage (V) = 12 volt

Watts = 18 W

Torque of the motor

Torque (T) = (P X 60) / (2 X 3.14 x n) …………….. (1)

= (18x 60) / (2 x 3.14 x 1250)

= 0.1375N-m

Torque = 137.5 N-mm

5.2 Design Calculations for Balancing

Mass of hub motor = 1.92 kg

Mass of batteries = 2.12*2 kg = 4.24 kg

Mass of wheels =0 .25 kg *2 = 0.5 kg

Mass of disc= 1.5 kg

Mass of frame= 1 kg

Mass of chassis= 1.25 kg

Mass of the whole system (M) = 1.92 + 4.24 + 0.5 + 1.25 + 1 + 1.5 = 11.51kg*9.81=112.91N

Given data:

Height of the centre (h)= 200mm =0.2m

Disc diameter (d)= 150mm =0.15m

Mass of disc (m) = 1.5 kg*9.81=14.715N

Speed of the motor (N)=1250 rpm

Angular speed of disc, (ω)=130.9rad/sec

Moment of inertia of the disc (I) $=mdr^2/2$………..… (2)

= 14.715*0.15*0.15/2 =0.165 N-m^2

We know that

Mghsinθ=Iωωp…………………………….. (3)

1. The vehicle is designed for the maximum tilt angle= 15^0

Therefore, the highest precision speed of the disc is

ωp= Mghsinθ/Iω = 112.91*9.81*.2*sin(15)/0.165*130.9 = 2.654 rad/sec

So highest required gyroscopic torque

T = Iωωp = 0.165*130.9*2.654 = 57.322 N-m^2/sec^2

2. The vehicle is designed for the maximum tilt angle= 20^0

Therefore, the highest precision speed of the disc is

ωp= Mghsinθ/Iω = 112.91*9.81*.2*sin(20)/0.165*130.9 = 3.507 rad/sec

So highest required gyroscopic torque

T = iωωp = 0.165*130.9*3.507 = 75.745 N-m^2/sec^2

3. The vehicle is designed for the maximum tilt angle= 10^0

Therefore, the highest precision speed of the disc is

ωp= Mghsinθ/Iω = 112.91*9.81*.2*sin(10)/0.165*130.9 = 1.781 rad/sec

So highest required gyroscopic torque

T = iωωp = 0.165*130.9*1.781 = 38.466 N-m^2/sec^2

5.3 CATIA Model of Self Balancing Bike

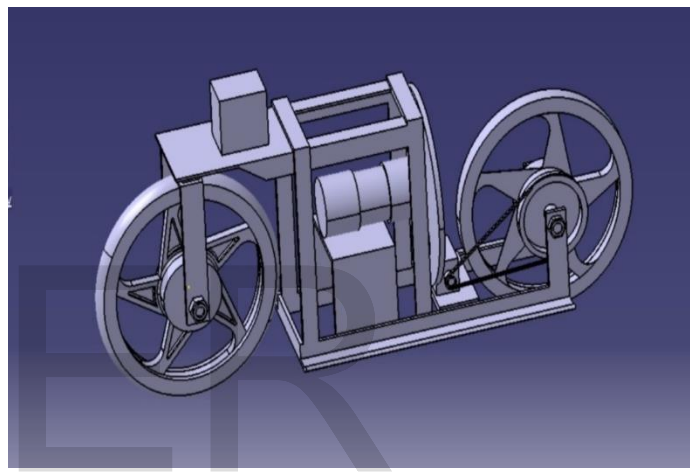


Fig 4 CATIA model of self balancing bike

6. ADVANTAGES AND LIMITATIONS

6.1Advantages

- Allows seniors or those physically unable to far travel longer distances.
- It is compact and requires very little maintenance.
- Allows you to travel faster than a regular bike(especially when going uphill)
- Easy to maintain, it's just an ordinary bike with an added battery and motor.
- Very useful for commuting quickly and avoiding traffic.
- If the battery is empty, you can just cycle normally, which may help to lose weight.
- High mobility & versatility - overcomes off-road, dirt, snow.

- Best suitable for handicapped people.

6.2Disadvantages

- It's heavy, which makes it difficult to store and very difficult to pedal up a hill if you run out of battery power
- Short battery life and long charging time
- Cost of the product increases

7. CONCLUSIONS

- The two-wheeled self-balancing bike was developed, incorporating a Control moment gyroscope (CMG) module.
- The CMG module in the bike generated sufficient torque to decrease the effect of the disturbance. In addition, the CMG module distributed the burden of the wheel motors.
- The performance was improved using a CMG module which generated higher torque.

8. FUTURE SCOPE

The future work of this project is to fix the wobble and asymmetry in motor speeds. In addition, verifying the performance using simulation. The improved CMG module will be developed and applied to experimentally demonstrate the improved performance.

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