# Design and Development of Inline Two Wheeler Self-Balancing Electric Bike

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***Abstract-* The two wheel vehicles during operation face the issue of balancing especially with untrained rider. Lot of time and fuel could be wasted by learners of the two wheel vehicle in balancing of the vehicle during training period. So, the main objective of this work is to design and develop a self-balancing electric two wheel vehicle which can balance itself with or without rider even vehicle may be in motion or stationary. The controller has two different objectives: to sense the velocity of vehicle in order to operate the actuator for manipulation of rake angle and other is the angle sensor to manipulate the steering angle with respect to vertical. The simultaneous adjustment of these two sensors will maintain the motorcycle stable. The actual set up will be experimented further aiming to balance the vehicle in different condition of loads.**

***Keywords-* *Self-balancing; electric vehicle; stability control; trajectory control.***

## I. INTRODUCTION

The bike which can balance itself is very popular project in robotics and engineering. There is lot of work going on about balancing bike and some are already done and a lot of work still need to done. The following section is our literature review on this particular topic.

In 1903, an Irish-Australian inventor Louis Grennan was first to patent a gyroscopic balancing a gyroscopic balancing vehicle.

In 1912, Russian inventor Dr.Pyotr Shilovsky in collaboration with Louis Grennan developed and designed a two wheel car with gyroscope sitting in the middle of the body of car for maintaining stabilizing force.

The self-balancing and two wheel robot SEGWAY HT is commercially available and it is invented by Dean Kamen who has design more than 140 systems.

In CES (Consumer Electronics Show) 2017 Honda unveiled the 'Riding Assist' technology which is the best example and working model of self balancing bike.

*Design:*

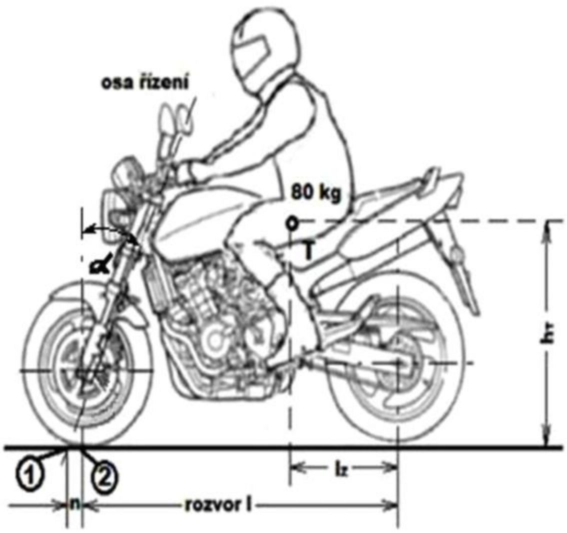



Fig. 1. Chassis Geomtry

*Main parameters of motorcycle chassis geometry:*

- Rake (α)
- Point of wheel contact (1)
- Steering axis and ground intersection (2)
- Trail (n)
- Wheel-base (l)
- Centre of gravity location (hT, lZ)

*Rake angle*: Rake angle of the front fork indicates the angle between the steering axis and the ground plane. A smaller rake angle of the front fork results in a greater stabilizing effect on the front fork. The rake angle (angle of steering axis) lies within about 24° to 30° to the ground.

*Steering axis and ground intersection*: Point of contact with the ground is indicated as wheel axis intersection perpendicular to the base of a stationary bike at a point of their intersection.

*Trail*: Trail is the distance between Steering axis and ground intersection and the Point of wheel contact. Trail has a significant impact on the stability and handling of a motorcycle.

*Wheel-base*: Wheelbase is the distance between the rotating axis of the wheels in a straight-line drive.

*Centre of gravity location*: Centre of gravity is determined by vertical and horizontal position. What is more important than examining its position on an unoccupied bike is observing the changes with an increasing load.

## II. CONCEPT

Methods to achieve self balancing are:

A) Change of trail length

B) Steering control

### *A. CHANGE OF TRAIL LENGTH-*

This picture is of negative trail length. When the bike is running at higher speed the trail length will get reduced. In order to achieve stability at low speed the trail length will get increased. This will contribute about 50% of balancing criterion.

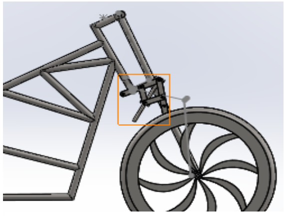


Fig. 2. Bike with negative trail length

Changing the trail length will be achieved by screw jack mechanism which is normally used to lift a vehicle.

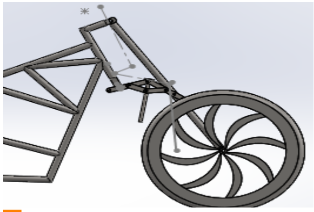


Fig. 3. Bike with positive Trail Length

*SCREW JACK SPECIFICATIONS-*

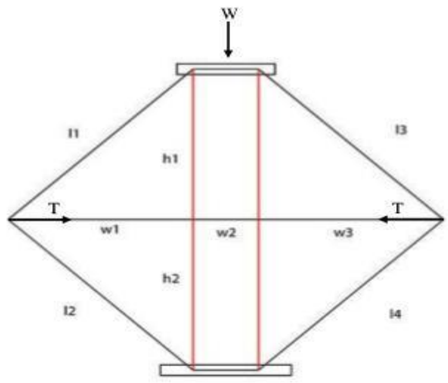



Fig. 4. Screw Jack

Length of each arm = L1 = L2 = L3 = L4 = 95mm
Length of the power screw = (w1+w2+3) = 350mm

wl = w3= 161.8 mm , w2 = 26.22 mm

Maximum lift of the jack = (hl+h2) = 300 mm

"β" is the angle made by link with horizontal when jack is at its lowest position

Cos (β) = (174-13.1)/(170)=18.72°

W= (load ×g) = (700×10) = 7000N = 7 kN

Tension, T = W/2 tan (β)= 1186.52 N

Total tension = 2T = W/tan (β)= 2373.05 N

For a power screw under tension we can take (α) = 124 $N/mm^2$ for mild steel

Let d' be the core diameter of the screw. But load on the screw is

Load = $(\pi/4) \times (d')^2 \times \beta$

So,

$2T = W/\tan (\beta = (\pi/4) \times d'^2 \times \alpha$

2T = 4.5 kN/tan (20.36') = 12123.44 N

$(d')^2=(W/\tan(\beta) \times (4/ \pi\times\alpha)$

Hence, d' 4.91 mm

Since the screw is subjected to torsional shear stress we adopt. d' = 8 mm

Taking pitch, P = 4mm

Outer diameter, do = d' + P = (8+4) = 12mm

Mean diameter, d = do -P/2 = 12-4/2 = 10 mm

CONSTRUCTION:

The jack is connected to the link situated between the suspension rod and the front assembly member. The screw jack is used because of it's capacity to withstand large loads.

WORKING:

The jack is device which is useful for lifting heavy loads. The mechanical device is connected to a rod and is attached to the servomotor. This helps smooth operation of the jack to take up the load exerted on the suspension bars. The links on which the jack is connected is firmly welded. The motor when stared makes the opening/closing if the jack within the stipulated time limit of 3-5 sec under varying loads. This movement is button actuated which is deployed at the throttle part of the bike

CALCULATIONS FOR VARIOUS PARAMETERS:

$$\text{Trail}_{\text{motorcycle}} = \frac{R_w \sin(A_r) - O_f}{\cos(A_r)}$$

Radius of wheel (Rw) = 17 inch = 17×25.4

= 431.8mm

MIN Angle of rake (Ar) = 17°

MAX angle of rake = 33°

Rake Offset length (Of) = 15mm

Therefore,

Positive trail length = 9.97cm

*MOTOR SPECIFICATIONS:*

- Torque required = 186.27 kg-m
- Rpm = 1800 rpm
- Load capacity =200 N
- Current = 90V DC

*B. STEERING CONTROL MECHANISM*

Steering control mechanism in which controller controls the amount of torque applied to the steering handlebar to balance the bicycle.

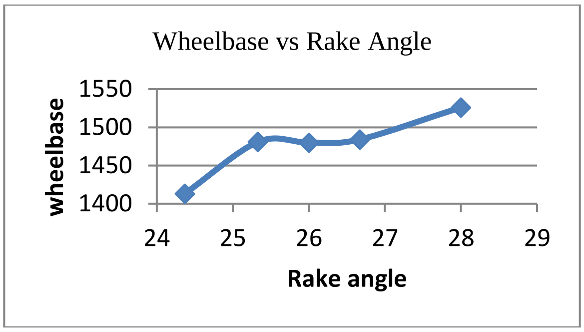
*MOTOR SPECIFICATIONS AND COMPONENTS:*

- Type of motor used- STEPPER MOTOR
- Load capacity- 10 kg
- Torque required- 10.33 kg-m
- Motor controller – L298N driver
- Sensor- gyroscope accelerometer GY-521 MPU6050
- Uno Aurdino – R3
- Current = 12V DC or 5V

III. EXPERIMENTATION AND GRAPHS-

On the basis of trail length criterion we performed some experiments and resulted the graph as below

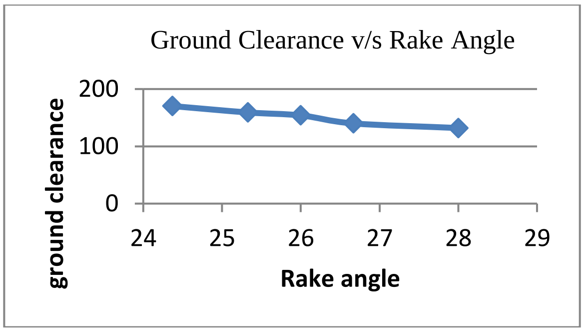
1. Change of wheelbase w. r. t. rake angle




Graph 1. Wheelbase v/s Rake Angle

As the rake angle is increased the wheelbase increases. This is ideal condition for which the stability of the vehicle can be increased.

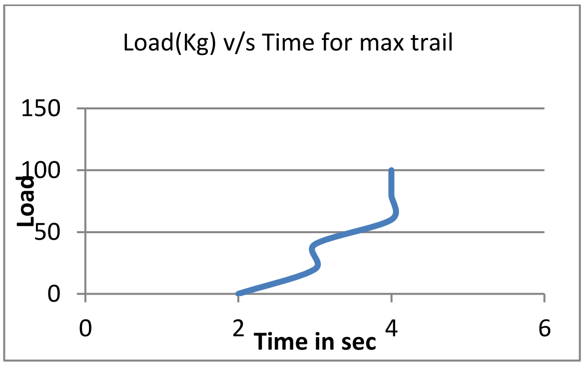
2. Change of clearance w. r. t. Rake Angle




Graph 2. Ground Clearance v/s Rake Angle

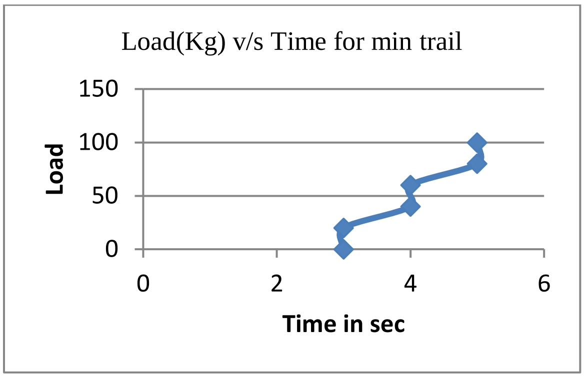
The ground clearance is reduced as the rake angle increases. This is due to the fact that wheelbase is increased. This helps in getting the centre of gravity of the bike to a point as low as possible making the bike heavy and thus increasing stability.

3. Time required to achieve max trail




Graph 3. Load(Kg) v/s Time for max trail

4. Time required to achieve min trail




Graph 4. Load(Kg) v/s Time for min trail

Time to achieve max and min trail is done to check the speed at which the mechanism works at different loading conditions.

## IV. ACKNOWLEDGEMENT:

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## V. CONCLUSION:

We showed that the front-wheel spin angular momentum and trail are necessary for self-stability, we do not deny that both are often important contributors. But other parameters are also important, especially the front-assembly mass distribution, and all of the parameters interact in complex ways. As a rule, we have found that almost any self-stable bike can be made unstable by misadjusting only the trail, or only the front- wheel gyro, or only the front assembly.

Conversely, many unstable bike can be made stable by appropriately adjusting any one of these three design variables, sometimes in an unusual way.

This gives us a method to check for stability by using the steering handle as we see in a cycle being driven at a very slow speed. At very slow speed since it is very difficult to handle the stability thus to counter it we use the movement of the handle bar to counter the fall effect. Similarly here even though increasing the trail length alone cannot give much stability thus the steering mechanism makes an integral part of the mechanism. The various tests made were regarding of trail length and other static constraints. The dynamic constraints such as it's effect on acceleration, deceleration, pitching, rolling are yet to be tested.

By making a hinged suspension we get a freedom of changing or adjusting the front wheel axis by making the trial length positive to negative.

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