STATIC & DYNAMIC BEHAVIOR OF SELF-BALANCING BIKES TECHNOLOGY: A MECHATRONICAL REVIEW PERSPECTIVE

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ABSTRACT

Two wheelers nowadays is the basic requirement for any person, but due to its statically unbalanced nature; it is quite difficult for everyone to adopt it. All the physical bodies in nature are balanced by their center of mass in the static condition and in a dynamic condition, conservation of momentum plays an important role. Here in this paper descriptive secondary analysis on different factors which are responsible for an imbalance of bike and the technology used by self-balanced bikes like Lit Motors C-1, Ryno Motors Ryno etc and the Honda Asimo robot are being discussed. Here future aspect of the self-balanced bike will examinew.r.to location and price in India.

KEYWORDS: *Self Balanced Bike, Centre of Mass, Conservation of Momentum, Lit Motors C-1, Ryno Motors Ryno & Honda Asimo Robot.*

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INTRODUCTION

Balancing Concept of Body

It is a well- known fact that every creature on this earth possesses mass & volume and due to gravity,the gravitational force also exerts on a body. This is general phenomena, but when we see things around us whether it is living or nonliving, we observe that the structure of human body is more complex and advanced in every aspect along with its balancing mechanism which is more complicated also.

It is necessary to understand balance first before understanding it being associated with anybody. Balance? What is this balance? We can define it in many ways like an even distribution of weight enabling someone or something to remain upright and steady. This is just the general definition. In a technical way, we can say that “it is an ability of the body to adjust the center of mass according to different positions.”Human Body is also like other complex bodies, but its system makes it different from others which coordinate with each other to maintain center of mass. The system is divided into four parts [1]:

- Vestibular System (inner ear balance mechanism)
- Visual system (Eyes)
- Proprioceptive system (muscles and joints)
- Brain

Hence all our system have their own function to maintain a physical balance of the human body but it is

not possible in dead bodies, due to uneven distribution of mass & non functioning of the system. By above explanation, we can only understand that body with unbalanced mass need system to balance itself or keep itself upright irrespective of any opposing force.

Technical Parameter Which Defines the Balancing of a Body

Before going deep inside the technical parameters, it is necessary to know the terms which are responsible for balancing the body i.e. center of mass, momentum.

- **Centre of mass:** The center of mass can be defined as the point in which whole mass of the body is concentrated. When an object is supported at its center of mass there is no net torque acting on the body and it will remain in static equilibrium.
- **Momentum:** It is simply defined as the mass in motion. It is a vector quantity which specifies both magnitude and direction. Its unit is kg m/sec (mks).

These are the two main terms which are necessary to understand for sensing the balancing concept. It is explained above that if a body is supported w.r.to center of mass then it would be in static upright condition. This means if the center of mass dislocates its position with respect to the support, then the body will lose its balance and even small momentum force is enough to make the body fall to the ground.

It is clear that statically body can be balanced only in two conditions:

- If the center of mass lie within line with the support means whenever we tilt the body its center of mass changes the position to be in line with the support.
- A surface area of the support w.r. to. center of mass location from the support means it is easy to keep the object still with the large surface area and short height with a uniform structure like cube but it is difficult for a pencil to stand on its tip because of the small surface area.

Things That Make Two Wheelers Unbalanced in Steady Condition as Compared to Four Wheelers

Two Wheelers

As we discussed above the factors behind the unbalancing of a body, now it is necessary to understand the same factor in two -wheelers and four wheelers in a static condition. In two -wheelers it was examined that its center of mass lies between the two -wheels above the ground. In the static condition, it is much difficult to maintain the line of action between the bases of the vehicle due to which little force is enough to disturb the balance of the two- wheeler.

Four Wheelers

In case of four wheeler, the height of the CG or CM is above the ground but it is stable in static conditions due to equally distributed mass and its four supports ie. Tyres with the large surface area as compared to bike due to normal disturbance or momentum. Force can affect its balance and its line of action always lies between the base of the vehicle.

Essence of Balancing in Motion

It is much difficult to balance the bike in static condition as compared to dynamic, so it is necessary to understand the concept behind it.

Conservation of Momentum Principle

It is practically observed that in the dynamic condition it is somehow two-wheelers get balanced. In running condition, spinning wheel has an angular momentum when we are sitting on the bike. The bike wheels make a system that obeys the principle of conservation of momentum and the direction of momentum remains constant.

When a vehicle is lined up in a certain way it is easy for a person who is sitting on it to move the vehicle but hard for any external force. So it is easy to maintain the balance of the bike, but not topple easily.

Due to steady conditions, the wheels of the bike doesn't spin and due to zero angular momentum, it is very easy for external force/torque to change the wheel direction thereby making the bike difficult to balance. [2]

PROBLEM STATEMENT

Balancing of two-wheeler in static condition is a very big problem and is dearly responsible for accidents, damage sometimes casualty also. It is necessary to have such technology which can be implemented in two-wheelers for self balancing to eliminate the accidental condition.

CONCEPT

Evolution of Self Balanced Bike Companies

Evolution of anything is arisen with the need. All the companies involved in the development of the self-balanced two-wheeler understand its importance due to their personal observation.

There are so many companies involved in evolution with self-balancing bike concept like BMW, Lit Motors C-1, Ryno Motors Ryno, Honda etc. We can see the evolution of self-balanced bike with Lit motors concept. Here the Founder of Lit motors Daniel Kim has seen the world that is more focusing on two-wheelers, but he observed that its too much danger to operate two-wheeler than four wheeler due to unbalancing nature of the two-wheeler which restricts the bike to be in the upright position in static condition without the stand.

Kim Daniel leads the way to the company's prototype solution: the all-electric C-1. He understood very well that gyro effect will be effective for self-balancing but to control its motion, a patented control system, featuring two gyros that spin in a compartment beneath the driver's seat, is the secret to the C-1's balancing act. These were the main part of the system to keep the bike in an upright condition. In spite of successful testing, there were certain flaws such as the size of the gyros were much bigger, mechanical control was not possible in same, as they adopted the anti-flip control system to control the gyros motion as per the position and after much struggle, Kim launched Lit motors in 2010.

Several prototypes later, Lit produced the C-1. Sleek and white with control-moment gyros (CMGs), it looks like a cross between a classic iPod and a light cycle from the movie Tron. In preliminary road tests, the C-1 prototype stayed upright as it rounded turns and reached 30 miles per hour. The planned-for specs of the finished vehicle are zero to 60 miles per hour in six seconds or less, a top speed of 100, and a 200-mile range, powered by a battery that is a fraction of the size of the one in a Tesla.[3]

Figure 1: Lit C-1 Design

Research Question

Why is Gyro Effect Responsible for Balancing?

To understand the gyro effect in self- balancing bike it is necessary to understand the gyro effect.

Gyro Effect & its Role in Self Balancing

A gyroscope is a spinning wheel or disc in which the axis of rotation is free to assume any orientation. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum. The gyroscopic effect comes into action when an axis of rotation of a rotating body (propeller, wheel etc) is turned round in a plane perpendicular to the plane of rotation of that body. It produces a gyroscopic reactive couple, which in turn itself produces a variety of effects on motion of cars, motorbikes, planes, and ships.[4]

From the above explanation, it is clear that conservation of momentum plays an important role in gyro effect. In the first part conservation of momentum, it is clearly understood that during in motion; gyro effect is produced by the spinning wheel and the angular momentum of the spinning wheel cancels the forces by external moment, hence it is easy to correlate the gyroscope phenomena with the self- balancing mechanism.

Self-Balancing Technology

Definition

This is the technology in which we are trying to keep the body in upright position in a static condition in spite of low surface area of contact and improper position of COM (center of mass & CG (Centre of gravity) of the body. In this technology we are concerned with mechanical, electrical and electronics phenomena. In this technology single phenomena is not enough for complete function. Hence for each function, a part of correlation of each field is necessary.

Necessity of Self Balancing Bike

It has been observed that most of the accidents happen due to using of two- wheeler rather than four wheeler. why? The answer is due to instability present in the bike as compared to car/four -wheeler. Whenever two -wheeler or anything is being hit by something its momentum becomes zero and due to imbalance, riders fall down and get injured. By adopting self -balancing technology in a bike, the possibility of the accidents can be reduced. Most of the middle -class families prefer two- wheeler only as per the economic conditions but everyone wants to feel four wheeler enjoyment in two -wheeler price and to give that feel it is necessary to improve the stability in a static condition. To achieve this companies felt it necessary to develop a technology by which two- wheeler can be in an upright position in the static condition.

PROPOSED WORKING PRINCIPLE

Working Principle of Self Balancing Technology

The working principle behind the self-balancing technology is same as the human body, but the difference is here mechanical function is performed by the mechanical equipment of the body and to control its operation control system is involved behind it.

In Honda, ASIMO humanoid robot is the concept and principle behind its operation. It was observed that human body is balanced due to its internal organ function but to keep the body stable, a system was developed in this robot to control the walking behavior. To attain the balancing condition different control systems are necessary to control the posture of the body which includes[4]

Floor Reaction Control

Firm standing control of the soles of the feet while absorbing floor unevenness.

Figure 2: Floor Reaction Control

Target ZMP Control

TheControl to maintain position was done by accelerating the upper torso in the direction in which it threatens to fall when the soles of the feet cannot stand firmly.

Figure 3: Target ZMP Control

Foot Planting Location Control

TheControl was done using side steps to adjust for irregularities in the upper torso which were caused by target ZMP control.

* ZMP = Zero Moment Point: The point when total inertial force is 0.

Figure 4: Foot Planting Location Control

To control all the position in robot I- A Walk technology was being adopted by the company by which robot can walk smoothly without any imbalance. According to this technology robot easily predict the next movement and shift its CG (Centre of gravity) as per requirement.[5]

The complete technology adopted by the company to stabilize the robot is called the riding assist technology in which sensors are responsible for controlling the posture of the body and hence stabilizing the body under different circumstances.

The same technology adopted in the Honda self-balanced bike to bypass the use of gyroscope for stabilizing the vehicle under static position

Figure 5: Control Block from I-Walk Technology

Conceptual Framework of the Proposed Working Principle

It is necessary to understand the working principle of a body under different condition. It includes the forces acting on the body, support of the body and the function of the different parts of the body.

Forces Acting on Body

It is important to understand the different forces acting on the body during static and dynamic condition by which it is easy to determine that what are the forces responsible for balancing and unbalancing nature of the body.

Support of the Body

In this era, we will understand the impact of supporting surface area in balancing of the body.

Function of the Different Parts of the Body

In this section, we will understand the function of different parts of the body and also understand the how each part affects the motion of the different part. In other sense correlate the function of the one part with the other.

Figure 6: Conceptual Framework

ASPECTS AS PER INDIAN MARKET

As per the Indian market, there are many aspects which should be considered before implementation of the technology.

Effect in Rural Road Condition

In India, there are two main parts i.e. urban and rural, among which 65% covers rural and 35% covers urban. The condition of the roads in the rural area is not that much good as compared to urban area. Due to which, it is a very much time consuming and unsafe to travel on village roads, sometimes it leads to severe injury and damage by accidents. Hence for these types of situations, we need such a type of technology in the vehicle which can sustain the two -wheeler in such abrupt condition.

Figure 7: The Village Road Condition in India (Makloor) [6]

By seeing the above road condition, it is clearly understood that riding a bike is much difficult as per Indian village road condition.

Effect in Metro City Traffic Conditions

In Indian metro cities the condition of road is quite good, but due to increase in population day by day; traffic is also increasing which leads to high rush in the roads. The urban residential mostly are always in hurry for their work due to which sometimes they get severe accidents which leads to high damage, sometimes casualty also. It is also observed that most the accidents occur due to slip and fall of the two-wheeler because of unbalanced nature of the bike. Hence with this

technology (Self-Balancing Technology) yet to be rolled out in India there is a chance to reduce the number of accidents.

The following below pictures indicate that there is more possibility of any severe incident which is not good. Hence we can say that, if there will be the replacement of such two-wheelers with self-balancing vehicle, then it will be advantageous in these conditions

Figure 8: Heavy Traffic Jam at National

Figure 9: Accident of a Bike [8]

Highway 24 [7]

If Honda is going to Launch Self-Balancing Bikes who will be Target Respondents to Purchase it?

In this condition following things will matter i.e.

- **Design and speed:** If the design of the bike is much attractive with good speed and pickup then young generation will attract more towards it. Some of the middle age person will also prefer to buy the same.
- **Price:** In India, price plays an important role in purchasing anything. If it will be launched at a reasonable price, then appropriate target respondents would be middle-class customers.
- **Service:** This factor plays an important role to capture the market. If service is good then it will be easy for an urban as well rural person to adopt the product.
- **Comfortability:** It should be comfortable as per the Indian culture especially for females and old age person who always prefer comfort level travel on two-wheelers.

Launching in India and Probability in Indian Markets

The markets in India are sluggish and basically rely on good products with an average cost optimization, so that it could be used in public as universally. If self-balancing bikes are launched in India, the properties to watch out for comforts to ride and reduction in the day to day accidents. These two basic features should be thoroughly assessed and would be on the agenda if launched in a huge market like India. Since it is yet to be launched in India, not much can be said about it.

IMPLEMENTATION OF THE TECHNOLOGY

Criteria for Implementing the Technology

Implementation of any technology requires preparation to analyze the future aspect as per the market condition. The main criteria for implementing the technology are:

- **Safety:** The technology should be safe enough for the rider by which time, money and life can be saved.

- **Cost:** This is the main criteria according to which it would be sustained and penetrate across all consumers of a vast market like India.
- **Service:** Now a day's implementation of new technology is not a big deal but to provide better service plays an important role to capture the market. There are so many companies in world launching every year with new technology but on some of them only sustain for a longer period due to their poor service.

PERFORMANCE ANALYSIS

Analyses of Performance in Different Situation and Comparison

Its performance analysis is based on different situation according to different location or area under different situations. In India, as already explained the condition in the urban and rural area. Its performance can be analyze by using it in all conditions where conventional two-wheeler gets failed. The condition are:

In Village Roads

It should be used in village roads for a certain period of time with convention bike without self-balancing phenomena and compare the results in accidental factor, travel time.

In Urban/City Area Traffic

Its analysis should be performed in traffic condition of the city and compare the incidents with the bikes without self-balancing technology so that the comparison can be made on the basis of data as well as the people opinions with their riding experience.

Application of Self Balancing Technology

Since self-balancing technology is mainly responsible for keeping the body in upright position under different condition hence it can be applicable to different area also where keeping things in upright condition is major issue, but self balancing technology in Honda two wheeler is without gyro effect so it is difficult to explain the application in other area but gyro effect self-balancing can be used for some other application. So its application can be in following area:

- **Segway:** It is used in segway for keeping it in statically upright condition.
- **Four wheeler:** As it was launched for one/two wheeler only it was observer that it can be used for four wheeler used in hilly areas where balancing of the vehicle is major issue. It can be helpful in double decker buses due to excess height.
- **Boats:** It can be used in Boats also but the balancing should be of gyro type to keep it balanced but here it can be helpful in adverse condition.

FUTURE ASPECT OF SAME CONCEPT IN OTHER FIELD

Here mostly we focused on applying the self-balancing technology in two-wheelers in which balancing in static condition is a major issue. It has been observed that this technology can be helpful in all such conditions ; whether it is static or dynamic so that it will be possible for us to eliminate the adverse condition due to unbalancing nature of the material.

CONCLUSIONS

From the above study, it was concluded that different forces are responsible for unbalancing of the body due to change in line of action of the center of mass with respect to the surface contact. Hence, it is necessary to maintain the line of action between the surface contact by different means that were used in Lit Motors (gyro effect), Honda self-balancing bike (sensors to maintain the trail effect) etc.

It is also concluded that self-balancing bike will be helpful to reduce the scenario of accidents by two-wheelers across the world this technology can be implemented of other purposes also.

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