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Design of Steering Mechanism for vehicles, based on leaning

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Abstract—A lean to steer mechanism is not as complicated as it sounds it is basically it's a type of steering principle which uses ball and socket joint for controlling its movement. This mechanism can be utilized for any type of vehicle including skateboards. In fact this mechanism was developed for skateboards and the first of its kind was seen in the year 1995 this board was made by the famous car company BMW the initial models were very bulky and very long with a large turning radius. The main advantage of this mechanism is that it makes the vehicle more stable at high speed turns so that even a four wheeled vehicle can take a turn like a sports bike by leaning to its side. By this leaning the centre of gravity of the vehicle comes in the line which is perpendicular to the axis of the wheels as shown in the figure below. This effect neutralizes the centrifugal force which is acting on the vehicle and makes it more stable during turning as the traction between the wheels and the road surface is increased due to leaning. It should also contain the features of an electric vehicle because the present situation is such that it demands those vehicle which causes less pollution as 73.0% of the CO2 emissions[1] is caused by roads vehicles.

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I. INTRODUCTION

What does lean to steer means? It working is quite simple when a person, riding the vehicle, wants to turn left he just has to shift his weight to the left side and whole vehicle will turn in the left direction. And when he wants to turn right he just have to shift his weight to the right side and whole vehicle will turn in the right direction. The first of its kind was seen in the year 1995 this was actually a skateboard and was made by the famous car company BMW the initial models were very bulky and very long with a large turning radius. The large turning radius was a big disadvantage for these kind of boards so the Company come up with new models of these skateboards but the use of this mechanism is not only restricted to skateboards. The car company called Nissan recently launched its first concept car called LAND GLIDER that uses this mechanism [2]. The main advantage of this mechanism is that it makes the vehicle more stable at high speed turns so that even a four wheeled vehicle can take a turn like a sports bike by leaning to its side. This effect neutralizes the centrifugal force which is acting on the vehicle and makes it more stable during turning. This paper is aimed at implementing it to common vehicles which will combine the advantages of leaning vehicles and electric vehicles.

II. LITERATURE REVIEW

A. Leaning Vehicle with Centrifugal Force Compensation[3]

A three wheeled vehicle, with two steerable front wheels and a driven rear wheels which may be either rider or motor powered includes steering linkage disposed adjacent to the lower end of the steering column having a handlebar attached to its upper end. The steering linkage pivotally couples a forward frame to a rear frame which supports the rider and includes the rear wheels and its mean for propulsion. The steering linkage includes a pivot shaft, a bearing housing and a mechanical connection for leaning the rear frame in a direction of a turn so as to compensate for centrifugal force encountered in turning the vehicle. The mechanical connection causes the rear frame to lean in a controlled relationship to the amount of rotation of the steering shaft, within rotational limits, to emulate the leaning action of a conventional bicycle when making a turn

B. Lean to Steer Recumbent Vehicle [4]

Two versions of recumbent human powered three wheeled vehicles are disclosed. Both are of the tadpole type with two front wheels and one rear drive wheel. Both versions lean into turns causing weight transfer towards the inside of turns to prevent roll over during turn at speed.

C. Recumbent Bicycle with Controlled Wheel & Body & Lean [5]

Three-wheeled vehicle with an adjustable leaning and steering mechanism, permitting operator controlled wheel and body lean as a vehicle is taking a turn. The vehicle has a leaning main frame that carries a pedal and crank assembly, recumbent seat and rear wheel. Towards the front of the vehicle, a perpendicular axle housing mounted with pivotal collar allows the main frame to lean right or left. Axle housing carries the cantilevered steering arm and adjustable steering lever. An axle runs through the axle housing and a spindle and control arm is pivotally connected to each end of the axle. Wheels to the main frame so that when the main frame is leaned all wheels lean, producing simultaneous wheel and body lean. Tie rod also connects each control arm to the adjustable steering lever rotating the control arm and axle as a unit. Operator supplies power to lean frame by use of arms pushing body right or left; the body, being cradled in seat causes frame to lean right or left. By rotating steering lever from vehicle to 45 degrees forward, the effect achieved is adjustable in relation to the amount of body lean allowing operator to make wide or tight turn and adjust the amount of lean to compensate for cornering forces to optimize the center of gravity or go straight and adjust body lean to compensate for road pitch.

D. *All-Terrain Sport Board & Steering Mechanisms for the Same*

An all-terrain sport board especially adapted for riding on rough out-door terrain large pneumatics wheels , a large frame and a spring steering mechanism that enables the rider to tip the board and the wheels to much greater degree than would be possible with a conventional boards. The steering mechanism provide polymeric shock absorbers of varying configuration to enhance the ability of the rider to make the athletics maneuvers and jumps with the board without undue turbulence in the ride.

E. *Electric Personal Transporter Based on Lean to Steer Mechanism*[6]

An electric personal transport is a vehicle which can carry persons from one place to another there are many kind of personal transporter and in that one type is stand up transportation vehicles these are used for traveling short distances so as to reach the destination in no time these vehicles are light in weight and some are so compact that they can be carried along the way.The result is a cost effective vehicle for multipurpose use in industries, large warehouse on footpaths etc. The objective behind is to develop a small, compact and light in weight personal electric transporter, a vehicle in a segment of stand up transportation which will combine the advantages of electric vehicles, lean to steer vehicles, and stand up transporter, That will be easily maneuverable and will be simple in design and will be fairly affordable so that even a small industry owner can buy the said personal electric transporter. This revolution of personal human transporter came in 2001 by a company called Segway. The Segway Human Transporter (HT) was a revolutionary new way of moving people around. Its stability seems an impossible feat. Due to a very robust and responsive control system coupled with various sensors and actuators, the Segway HT is almost impossible to falloff [7]

III. FORMULATION OF PRESENT WORK

A. *Trikke* [8]

The Trikke three-wheeled cambering vehicles are human powered machines that utilize Trikke Tech's patented technology to allow a rider to propel a chainless, pedal-less device forward without ever touching foot to ground. This construct provides a stable 3-point platform that lets riders lean into the turns while all three wheels remain in contact with the ground. An experienced rider may reach speeds of up to 18 mph (29 km/h) on flat ground, ride 50 miles in one day, and climb steep hills (with considerable practice). Propelling a Trikke uphill requires substantially more effort and effective movement, but can be mastered with experience. The Trikke requires roughly the width of a downtown sidewalk (1-1.5 m) but can also operate on city streets. Mastering the correct form necessary for efficient propulsion requires practice, as it is not a familiar movement for most new riders.

Figure 1. Actual picture of TRIKKE

Riders often claim to need a few longer rides to find the "sweet spot" or ideal movement pattern to effectively ride a Trikke. Its three point contact structure makes it reasonably stable, but wet pavement or leaves, or rough gravel under the wheels can cause a rider to possibly tip over or skid, so helmets are highly recommended.

IV. DESCRIPTION OF LEAN TO STEER MECHANISM

The fundamental problems with cars and motorcycles are flow-on effects from a very early and virtually omnipresent design decision - connecting the steering input directly to the front wheels. Steering a car in this way throws all the weight to the outside of the corner - only the width of the wheelbase saves the car from toppling over sideways in the turns. motorcycles have the ability to lean into the turns, but the dynamics of countersteering to achieve the lean angle are complex for new riders, and the rider's control over the vehicle's tilt is completely reliant upon traction - lose traction, and you're out of control and in trouble. tilting 3- and 4-wheelers a step in the right direction, says james, but they still can't offer total stability because the steering is still directly connected to the steering wheel - so when traction is lost or the vehicle goes to topple under cornering forces, the driver is completely responsible for any corrective action; a fundamental issue with any vehicle that uses direct steering control [9]

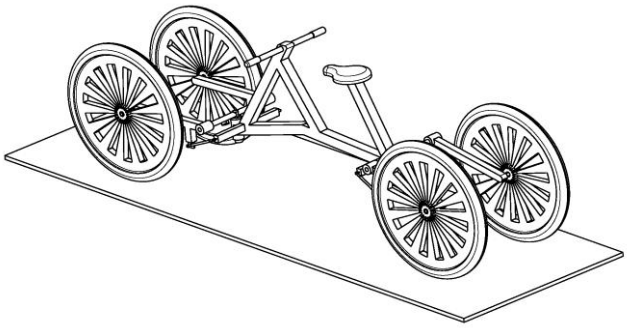

Figure 2. Isometric view of the concept of the mechanism

A Lean steering mechanism uses leaning action of the rider to steer the vehicle by help of combined movement of linkage.

There are four independent wheels held between the wheel forks, which are attached to the vehicle on either side in front or rear part of vehicle via central steering link. fork are attached to the central steering with the help of ball bearings as shown making it to swing in two directions (i.e. up and down) the movement of the wheel forks is further constrained with a spherical rod end joint connecting the main frame to the wheel forks,

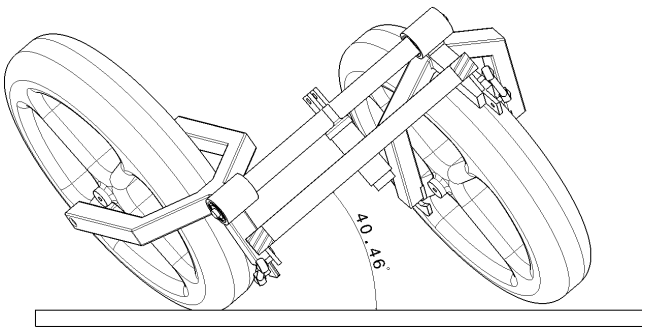

Figure 3. View of the vehicle when taking a turn

to provide the required degree of freedom for the vehicle for effective working. At stationary condition the vehicle rest on its four wheels but when there is a rider on board, the vehicle uses its lean to steer motion to maneuver itself by using simple leaning of the rider. When the rider leans to any one side in which he or she has to go the main frame also gets tilted in that direction so to understand this let us assume that the rider wants to go in left direction so he will lean to his left. As a result both the wheel forks of left side will swing upwards but as they are restricted by the rod end bearings they will make the central steering links to revolve on their respective central axis and as a result central steering links will turn the wheel in such a manner so that the vehicle can make a left turn. The turning radius is depended upon the amount of leaning, the more you lean smaller will be the turning radius. To prevent the rider from falling off the maximum amount of tilting of the vehicle is also restricted and so is the turning radius and it varies from 4.5 foots to 9.5 foots

V. BASIC COMPONENTS IN LEAN TO STEER MECHANISM

A. Frame

A frame is a main supporting structure of the vehicle This means that the entire body weight acts on the frame, which is then transferred to the wheels through the other parts of the vehicle.

B. Steering Linkage

The steering linkage, directs the vehicle when the person riding it leans in either of the directions. It can be considered as a simply supported beam with its ends supported in bearings & weight acting at the center of the link.

C. Rod End Bearing

A mechanical articulating joint also known as a helm joint N. America or rose joint (U.K. and elsewhere), A ball swivel with an opening through which a bolt or other attaching hardware may pass is pressed into a circular casing with a threaded shaft attached. The threaded portion may be either male or female. We have used female rod end bearings with M10 threads. Such joints are used on the ends of control rods, steering links, tie rods, or anywhere a precision articulating joint is required.

VI. DESIGN CALCULATIONS

A. Calculation for Degree of Freedom

According to Kutzbach Criterion for plane mechanism, the Degree of Freedomcan be calculated by,

l.....number of links

j.....number of joints

h.....number of higher pairs

From the fig.

No. of links=8

No. of joints/lower pairs=9

No. of higher pair=2

$$n = 3(l-1) - 2j - h$$

$$n = 3\,(8 - 1) - 2 \times 18 - 2$$

$$n = 1$$

$$n = 1$$

This can be verified from the mechanism as it requires only one input link movement for the entire mechanism to work.

B. Design Calculations

The steering linkage directs the vehicle when unbalanced weight acts on it. It can be considered as a simply supported beam with its ends supported in bearings & weight (of the person standing on the vehicle obtained through load distribution) acting at the center of the link.

$$M = \frac{WL}{4}$$

$$M = \frac{500 \times 382}{4}$$

M=38200 N-mm

As we know that,

$$\sigma b = m/z$$

σb----------bending stress

Z----------section modulus for circular cross section

Therefore,

$$Z = \pi \times d^3/32$$

$$Z = \pi \times d^3/32$$

Z=169.64 mm3

$$\sigma b = 38200/169.64$$

$$\sigma b = 225 \text{ N/mm2}$$

From the design data book, for SAE 1040(commercial name EN8)

Seb=260 N/mm2 >σb

Hence, the design is safe.

C. Design of Frame

The entire body weight acts on the frame which is then transferred to the wheels through linkages & the support reactions from the wheel is obtained. Now for the sake of calculations suppose that the load acts on the center of the beam of frame. For a simply supported beam having a load at its center,

$$M = wl/4$$

$$M = 1000*633.48/4$$

M= 158370 N-mm

$$\sigma b = m/z$$

σb----------bending stress

Z----------section modulus for hollow square

Therefore,

$$Z = b^4-h^4/6*b$$

$$Z = 25.4^4-19.4^4/6*25.4$$

Z = 1801.73 mm3

$$\sigma b = 158370\ 1801.73$$

$$\sigma b = 87.89 \text{ N/mm2}$$

From the design data book, for

Seb= 120 N/mm2 >σb

Hence, the design is safe.

VII. CONCLUSIONS

The results of implementing the lean to steer mechanism to a electric vehicles are as follow

- Results of Synthesis Maximum Traversal Angle in Each Direction= 10
- The lean to steer mechanism has its own advantages like at high speed turning the vehicle is more stable than any other four wheeler [3]
- Due to leaning the center of gravity of the vehicle is always balanced and the resultant forces and their reactions are lined up so no axial force on the bearings [6]
- As this mechanism contains no rigid axle between the two wheels hence all the four wheels are always in contact with ground and hence the traction is increased[6]
- At very high speeds there is negligible speed wobble [10]
- The electric driven vehicles are 11 times more energy efficient then a average car and 17 times more energy efficient than a large SUV[9]
- As the vehicle is an electric vehicle its prime mover that is an electric motor is 90% to 95% efficient so we get 95% of the power of the batteries in the road wheels[9]

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