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RESEARCH ARTICLE OPEN ACCESS

FOUR WHEEL STEERING SYSTEM

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ABSTRACT:

This paper comprises of the Design & Fabrication of a Four Wheel Steering mechanism which improves manoeuvrability in trucks, cars, trailers & other four wheelers. In general two wheel steering vehicles, the rear wheels do not play any role in association with the steering, i.e they follow the path of the front wheels. In a four wheel system the rear wheels are made to turn left & right as per the requirements. To keep the operation as simple as possible a computer controlled mechanism can be incorporated for the rear wheels. The rear wheels can be controlled in the following fundamental ways: At slow speeds the rear wheels turn in the opposite direction of the front wheels. This can reduce the turning radius approximately by 21%. At faster speeds on the highway, the rear wheels are made to turn in the same direction of the front wheels. This improves the lane changing manoeuvrability & is particularly beneficial for vehicle towing.

I. INTODUCTION:

A. What is steering?

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship, boat) or vehicle (car, motorcycle, and bicycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide the steering function. The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints, to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear–wheel steering. Tracked vehicles such as bulldozers and tanks usually employ differential steering that is, the tracks are made to move at different speeds or even in opposite directions, using clutches and brakes, to bring about a change of course or direction.

II. FOUR WHEEL STEERING:

Four-wheel steering, 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning manoeuvres. It should not be confused with four-wheel drive in which all four wheels of a vehicle are powered. It improves handling and helps the vehicle make tighter turns. Production-built cars tend to under steer or, in few instances, over steer. If a car could automatically compensate for an under steer /over steer problem, the driver would enjoy nearly neutral steering under varying conditions.

4WS is a serious effort on the part of automotive design engineers to provide near-neutral steering. The front wheels do most of the steering. Rear wheel turning is generally limited to half during an opposite direction turn. When both the front and rear wheels steer toward the same direction, they are said to be inphase and this produces a kind of sideways movement of the car at low speeds. When the front and rear wheels are steered in opposite direction, this is called anti-phase, counter-phase or opposite-phase and it produces a sharper, tighter turn. The concept is simple. Rather than controlling a car solely by the angle at which the front tires meet the road the method used by wheeled vehicles since the horse-drawn carriage, four-wheel steering turns the wheels simultaneously at both ends of the car. The idea is intuitively appealing to any city driver who has ever pulled up to a too-short parking space and wished he could point all four tires toward the curb and crab right in.

Not so easy. For starters, the rear wheels of a four-wheel-steer car do not always turn in tandem with the front wheels. Depending on the speed of the car, the rear wheels may turn in the same direction (same-side steering) as the front wheels, or in the opposite direction (counter steering). Most of the new four-wheel-steer autos are capable of both counter steering and same-side steering. In sharp, slow-speed turns, counter steering can shave a full yard off a standard sedan's turning radius. At high speeds, however, counter steering can make a car dangerously unstable, while same-side steering actually improves the ride.

In a four-wheel-steer car, this high-speed sway can be damped or even eliminated through the use of same-side steering. When the rear wheels are turned at the same time and in the same direction as the front wheels, the back end turns with the front, and the cornering forces occur at both axles simultaneously. The car slides smoothly to the side without sway or fishtail.

B.TYPE OF STEERING MECHANISM USED:

Ackerman's Steering Mechanism

III. Ackerman's Steering Mechanism:

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii. The intention of Ackermann geometry is to avoid the need for tyres to slip sideways when following the path around a curve. The geometrical solution to this is for all wheels to have their axles arranged as radii of a circle with a common centre point. As the rear wheels are fixed, this centre point must be on a line extended from the rear axle. Intersecting the axes of the front wheels on this line as well requires that the inside front wheel is turned, when steering, through a greater angle than the outside wheel. Rather than the preceding "turntable" steering, where both front wheels turned around a common pivot, each wheel gained its own pivot, close to its own hub. A linkage between these hubs moved the two wheels together, and by careful arrangement of the linkage dimensions the Ackermann geometry could be approximated. This was achieved by making the linkage *not* a simple parallelogram, but by making the length of the track rod (the moving link between the hubs) shorter than that of the axle, so that the steering arms of the hubs appeared to "toe out". As the steering moved, the wheels turned according to Ackermann, with the inner wheel turning further. If the track rod is placed ahead of the axle, it should instead be longer in comparison, thus preserving this same "toe out".

IV. MODELING:

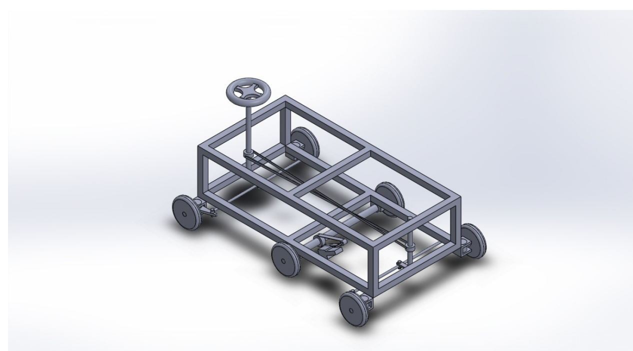

FIG 1 MODELING

V. CALCULATION:

C. Finalization of track width and wheel base:

After many iterations of track width and wheel base corresponding to Ackermann Geometry and rule book these dimension where finalized.

Wheelbase	0.175 m
Front track width	1 m
Rear track width	1 m

D. Calculation of Forces on Knuckle

Let M: Mass of model

F_x: Longitudinal Force

F_y: Lateral Force

F_z: Vertical Force

m_1: Mass on front wheels m_2: Mass of rear wheels

μ: Coefficient of friction

Now Mass of the front wheels $m_1 = 0.5$ kg

Mass of the rear wheels $m_2 = 0.5$ kg

$m = m_1 + m_2$; m=1 kg and μ=0.3

$F_x = \mu mg$

$= 0.3*1*9.81$

$= 2.943$ N

$F_y = Mv^2/R$

$= 1*(0.5)^2/1.5$

$= 0.166$ N

$F_z = mg$

$= 1*9.81$

$= 9.81$ N

E. Calculation of Ackermann Angle, Inner and Outer Angle and Ackermann Percentage:

Ackermann angle is calculated by using formula,

Ackermann angle = $\tan^{-1}$\{Kingpin to Kingpin distance/ (2 * Wheelbase)\}

$= \tan^{-1}\{0.70/(2*0.175)$

$= 63.43^0$

Based on above fixed values of wheelbase and track width inner and outer angles were calculated, by using Ackermann geometry formula.

F. Based on these three criteria's inner and outer angles were fixed they are:

1) Locking conditions of model
2) Instantaneous center
3) Ackermann percentage

Angle inside for 100% Ackermann = $\tan^{-1}$\{wheelbase/ ((wheelbase/tan Θ_o) – track width)\} – Θ

$= \tan^{-1}\{0.175/((0.175/\tan 63.43) - 1)\} - 63.43$

$= 21.42$

Ackermann percentage = (Inner angle – Outer angle)/Angle inside for 100% Ackermann

$= (41 - 30)/ 21.42$

Parameters	Values
Inner Angle	41^o
Outer Angle	30^o
Ackermann Angle	63.43^o
Ackermann Percentage	52.325%
Turning Radius	1.5m

G. Calculation of required steering part lengths:

Adopting a fixed value for steering effort, lengths of various steering parts like: pitman arm, radius of wheel, stub axle length and steering arm length were calculated.

F_1=Force transmitted from pitman arm to steering arm.

By using these equations,

F1 = (F_x *spindle axle length)/pitman arm length

= (2.943* 0.06)/0.085

= 2.077N

Steering effort = (F1*pitman arm length)/ radius of steering wheel

= (2.077* 0.085)/ 0.28

=6.1N

After many recapitulations lengths of steering parts were fixed

Parameters	Value
Steering effort	6.1N
Spindle axle	0.06m
Radius of steering wheel	0.28m
Pitman arm length	0.085m

H. STEERING COLUMN:-

Steering column fails in torsion.

Using,

$$T/J = \tau/r$$

Where T: Torque acting on column
τ: shear stress acting on column
J: Polar modulus of rigidity
r: Radius of wheel
Now, torque is calculated by using
T = Steering Effort * Radius of wheel
= 6.1 *0.28
= 1.708 Nm

Outer diameter	0.016m
Inner diameter	0.012m

Tie rods:-

Tie rods fails in buckling.

$P_{cr} = \pi^2 EI/ \{L_e\}^2$

Where P_{cr}: Critical Load acting on tie rods.
E: Young's modulus of elasticity $=200*10^9$ N/m^2
I: Moment of Inertia =2199.11
L_e: Effective length of tie rods which in this case is
L_e =Length of tie rod /2
= 0.30/2
=0.015 m

Therefore P_{cr} based on above formula is 1929.27 kN.

Now Slenderness Ratio = L_e/R
Where R: Radius of gyration = 5
$R = \{I/A\}^{0.5}$
Here $A= \pi/4\ [d_o^2 - d_i^2]$
Where d_o: Outer diameter of tie rods
d_i: Inner diameter of tie rods

Depending upon the criteria of slenderness ratio for steel short column to be less than 50, various values were chosen for tie rods dimension and based on above criteria we chosen a safe dimension.

Outer diameter	0.016 m
Inner diameter	0.010m

VI. ADVANTAGES OF FOUR WHEEL STEERING:

1. Computer-controlled four wheel steering can be switched on and off and has an effective trailer towing mode.

2. A computer determines how much and in which direction the rear wheels should move, and whether the rear wheels should turn the same direction as the front wheels or in the opposite direction. The movement is variable up to a couple of inches.

3. At slow speeds, the rear wheels move the opposite direction of the front wheels. This makes for easier parking and manoeuvring.

VII. CONCLUSION:

Having studied how 4WS has an effect on the vehicle's stability and driver manoeuvrability, we now look at what the future will present us with. The successful implementation of 4 Wheel Steering using mechanical linkages & single actuator will result in the development of a vehicle with maximum driver manoeuvrability, uncompressed static stability, front and rear tracking, vehicular stability at high speed lane changing, smaller turning radius and improved parking assistance. Furthermore, the following system does not limit itself to the benchmark used in this project, but can be implemented over a wide range of automobiles, typically from hatchbacks to trucks. This provides one of the most economical steering systems for improved manoeuvrability and driver's ease of access. With concepts such as "ZERO TURN" drive as used in "Tata Pixel" and "360^0 Turning" used in "Jeep Hurricane" when added to this system, it will further improve manoeuvrability and driver's ease of access.

VIII. REFRENCES:

[1] K. Lohith, Dr. S. R. Shankapal, & Mr. H. Monish Gowda "Development of Four Wheel Steering System for a Car," SAS Tech Journal, vol. 12, pg. 90-97, Issue 1, April 2013.

[2] Honda official website http://automobiles.honda.com/civic-sedan/specifications.aspx

[3] Dr. Kirpal singh "AUTOMOBILE ENGINEERING" standard publisher's distributors, volume 1. 12th edition 2011

[4] V. B. Bhandari " Design of Machine Elements" McGraw Hill Education India Pvt. Ltd., vol. 3, 11th Edition, 2013.

[5] S. C. Chang, "Synchronization in a steer-by-wire vehicle dynamic system", International journal of engineering science, 45(2-8), 628-643, 2007

[6] C. D. Gadda, P. Yih, J. C. Gerdes, "Incorporating a model of vehicle dynamics in a diagnostic system for steer-by-wire vehicles", 2004

[7] **Ta-Chih Hsiao ,DarenChen ,PaulS.Greenberg, KennethW.Street** "Effect of geometric configuration on the collection efficiency of axial flow cyclones" Journal of Aerosol Science 42 (2011) 78–86

[8] The particle collection efficiencies of axial flow cyclones with eight different geometric configurations, operated at 50 lpm aerosol flowrate, have been evaluated in this study.

[9] Zhongli Ji , Zhiyi Xiong , Xiaolin Wu , Honghai Chen , Hongxiao Wu "Experimental investigations on a cyclone separator performance at an extremely low particle concentration" Powder Technology 191 (2009) 254–259