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Four Wheel Steering Mechanism

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Abstract:
The basic aim of steering is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears. One of the fundamental concepts is that of caster angle – each wheel is steered with a pivot point ahead of the wheel; this makes the steering tend to be self-centering towards the direction of travel. When the driver turns the steering wheel, a shaft from the steering column turns a steering gear. The steering gear moves tie rods that connect to the front wheels. The tie rods move the front wheels to turn the vehicle right or left. The steering system must provide control over the direction of travel of the vehicle; good manoeuvrability for parking the vehicle; smooth recovery from turns, as the driver releases the steering wheel; and minimum transmission of road shocks from the road surface. The steering system provides control over direction of travel, good manoeuvrability, smooth recovery from turns, and minimum transmission of road shocks.

I. INTRODUCTION

Four wheel steering is a method developed in automobile industry for the effective turning of the vehicle and to increase the manuverbility. In a typical front wheel steering system the rear wheels do not turn in the direction of the curve and thus curb on the efficiency of the steering. In four wheels steering the rear wheels turn with the front wheels thus increasing the efficiency of the vehicle.

The direction of steering the rear wheels relative to the front wheels depends on the operating conditions. At low speed wheel movement is pronounced, so that rear wheels are steered in the opposite direction to that of front wheels. At high speed, when steering adjustments are subtle, the front wheels and the rear wheels turn in the same direction. By changing the direction of the rear wheels there is reduction in turning radius of the vehicle which is efficient in parking, low speed cornering and high speed lane change. In city driving conditions the vehicle with higher wheelbase and track width face problems of turning as the space is confined, the same problem is faced in low speed cornering. Usually customers pick the vehicle with higher wheelbase and track width for their comfort and face these problems, so to overcome this problem a concept of four wheel steering can be adopted in the vehicle. Four wheel steering reduces the turning radius of the vehicle which is effective in confined space, in this project four wheel steering is adopted for the existing vehicle and turning radius is reduced without changing the dimension of the vehicle.

II. APPLICATION OF FOUR WHEEL STEERING

Parallel parking

Zero steer can significantly ease the parking process due to its extremely short turning footprint. This is exemplified by the parallel parking scenario which is common in foreign countries and is pretty relevant to our cities.

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Here a car has to park itself between the two other cars parked on the service lane. This maneuver requires a three way movement of the vehicle and consequently heavy steering inputs. More over to successfully park the vehicle without incurring any damage at least 1.75 times the length of the car must be available for parking a two wheeled steer car. As can be seen clearly the car requires just about the same length as itself to park in the spot. Also since the 360 degree mode does not require steering inputs the driver can virtually park the vehicle without even touching the steering wheel. All he has to do give throttle and brake inputs and even they can be automated in modern cars. Hence such a system can even lead to vehicles that can drive and park by themselves. Another driving maneuver that frequently becomes cumbersome and even dangerous is changing lanes at fairly high speed. Although this is less steering sensitive this does require a lot of concentration from the driver since he has to judge the space and vehicles behind them. The vehicle with arrows is the model under study.

As can be seen from the figure the vehicle can turn with hardly any space requirement with a single steering action and also resume without any corrective inputs. Thus it also acts as a driver aid helping relatively inexperienced drivers make quick lane changes even at high speeds. The company Honda Prelude manufactured the first four wheel steering car and it defines four wheel steering as the effect of the 4WS mechanism acting in this way was non-linear steering. That is, the effective steering ratio varied from a low ratio at small steering angles, to high ratio at large angles. This means more steering angle input is required to perform a gradual turn, making the car less twitchy and more relaxed to drive at high speed, without requiring constant corrections; while less steering angle is required to perform a tight-radius turn, giving the car a go-kart like feel during tight maneuvers. The observed effect while driving might be best imagined as a variable effective wheelbase, from a long wheelbase at small steering angles, to very short wheelbase at large angles.

III. DESIGN CALCULATIONS

Specifications

Length: 3 feet
Width: 20 inch
Wheel size: 16 inch

1) Ackerman arm angle (α):

$$\alpha = [\tan^{-1}[\frac{\text{king pin center to center distance /2}}{\text{wheel base}}]$$

$$\tan^{-1}\frac{1250/2}{1500}$$

$$\propto = 22.61$$

Ackermann Arm Radius(R)

$$\sin \propto = y/r$$

y= {king pin center to center distance –length of tie rod}/2

y= {1250-1023}/2=113.5mm

$$R = 113.5/SIN\ (22.61)$$

$$R = 295.5mm$$

ARM BASE $y = 113.5mm$

Turning Circle Radius

By Ackermann Mechanism

$$\sin(\propto + \emptyset_{if}) = \frac{Y + X}{R}$$

Where

α = Ackermann angle

$\emptyset_{if} =$ inside lock angle

y = arm base

x = linear displacement of rack for one rotation of the pinion {3.41*m*zp}

x=62.83mm

R = Ackermann arm radius

$$\sin(22.61 + \emptyset_{if}) = \frac{113.5 + 62.83}{295.5}$$

$$\emptyset_{if} = 14.02$$

Therefore inside lock angle of front wheel = 14.02.

Calculations of the position of centre of gravity with respect to rear axle

$$R^2 = a_2^2 + R_7^2$$

$a^2 =$ distance of cg from rear axle

$$w_f = \frac{w \times a_2}{L}$$

$$48 = \frac{80 \times a_2}{1500}$$

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$a_2 = 900mm$

$l - a_1 = a_2$

$-a_1 = a_2 - l$

$1500 - 900$

$a_1 = 600mm$

$R^2 = a_2^2 + R_1^2$

$87320.5 = 900^2 + R_1^2$

$R_1 = 850.10\ mm$

Position of instantaneous centre

$\tan\emptyset_{if} = \frac{c_1}{R_1 - \frac{tw}{2}}$

$\tan(14.02) = \frac{C_1}{850 - \frac{1250}{2}}$

$C_1 = 56.20mm$

$c_1 + c_2 = R$

$56.20 + C_2 = 295.5$

$=239.3mm$

3) To find the outer angle of rear wheel

$\tan\emptyset_{or} = \frac{c_1}{R_1 + \frac{tw}{2}}$

$= \frac{56.20}{850.10 + 625}$

$= \tan^{-1}(0.)$

$\emptyset_{or} = 4.25$

To find the inner angle of front wheel

$\tan\emptyset_{if} = \frac{c_2}{\frac{R_1 - tw}{2}}$

$= \frac{239.3}{850.10 - 625}$

$= \tan^{-1}(1.063)$

$\emptyset_{if} = 46.749$

To find the outer angle of the rear wheel

$\tan\emptyset_{or} = \frac{c_2}{R_1 + \frac{tw}{2}}$

$= \frac{239.3}{850.10 + 625}$

$\emptyset_{ir} = 9.21$

Calculating the turning radius for same steering angle

To find turning radius R

$R^2 = a_2^2 + L^2(\cot^2\delta)$

$\cot\delta = \frac{\cot\theta + \cot\emptyset}{2}$

θ = total inner angle of vehicle

$\emptyset$ = total inØner angle of vehicle

$\cot\delta = \frac{\cot(14.01 + 46.74) + \cot(4.25 + 9.21)}{2}$

$\cot\delta = 2.36$

$R^2 = 900^2 + 1500^2 + \cot^2\delta$

R = 3652.61mm

Now

$R^2 = a_2^2 + R_1^2$

$(3652.61)^2 = 900^2 + R_1$

$R_1 = 3539mm$

Calculations for c_1&c_2

$\tan\theta_{if} = \frac{c_1}{R_1 - \frac{tw}{2}}$

$\tan(14.01) = \frac{c_1}{3539 - 625}$

$c_1 = 727{,}32mm$

$c_1 + c_2 = R$

$727.32 + c_2 = 3539$

$c_2 = 2811.77$

Reconstituting the new values of c_1& c_2 in inside angle and outside angle formulas to find the original values

$\tan\theta ir = \frac{c_1}{R_1 - \frac{tw}{2}}$

$= \frac{727.32}{3539 - 625} = 14.01°$

$\tan\emptyset_{or} = \frac{c_1}{R1 + \frac{tw}{2}}$

$\frac{727.32}{3539 + 625} = 9.90°$

$\tan\emptyset_{if} = \frac{c_2}{R1 - \frac{tw}{2}}$

$\frac{2811.77}{3539 - 625} = 43.97°$

$\tan\emptyset_{of} = \frac{c_2}{R_1 + \frac{tw}{2}}$

$\frac{2811.77}{3539 + 625} = 34.02°$

All wheels angle

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$\emptyset_{ir} = 14.01°$
$\emptyset_{or} = 9.90°$
$\emptyset_{if} = 43.97°$
$\emptyset_{0f} = 34.02°$
Total inner angle $\theta_{if} + \theta_{ir} = \theta$
$\theta = 14.01 + 43.97$
$\theta = 57.90$
Total outer angle of the vehicle
$\emptyset = \emptyset_{of} + \emptyset_{or}$
$= 9.90 + 34.02 = 43.92°$
$\text{Cot}\delta = \cot\frac{(57.90)+\cot(43.92)}{2} = 0.80$
$R^2 = a_2^2 + l^2(\cot^2\delta)$
$=900^2 + 1500^2 \times 0.64 = 1500\text{mm}$

Turning circle radius of the whole car = 1500mm.

IV. WORKING MECHANISM OF 4 WHEEL STEERING

Our main objective was to achieve the counter phase mechanism. In counter phase mechanism if we turn the steering wheel to right front 2 wheels will move to right side and rear two wheels will move to the left side. And if we turn the steering wheel to left the front two wheels will move to left and rear two wheels will move to right. To achieve this we used chain and sprocket gear set in our project.

When the steering wheel is in initial position

Here we can see that if we do not turn the steering wheel both front wheels and rear wheels will remain in the same line direction. There will be no movement of wheels. So vehicle will move straight.

When the Steering Wheel Is Turning To Right

Here the steering wheel is turning to the right side. As the steering is connected to the wheel so the steering system will move to the right side along with the front two wheels as those wheels are connected to the steering system. And as per our mechanism rear wheels will move to the opposite direction which is left side. We used chain and a reverse sprocket gear system to change the right side movement of front wheels to left side movement in the rear wheels. It is approximately 3:1 in ratio. That means if the front wheels moves 30 degrees right side then the rear wheels will move to 10 degrees left side.

When the Steering Wheel Is Turning To Left

Here the steering wheel is turning to the left side and steering system along with the front two wheels will move to the left side. Because of the reverse mechanism the rear 2 wheels will move to the right side. Here the movement angle will be as same as it was for the right side movement of front wheels.

Applications

There is lots of application of 4 Wheel steering in our practical life. 4 Wheel Steering helps us to do those things which we find difficult to do with 2 Wheel Steering. Also helps us in various ways

parking

The first and most important application of 4WS is to reduce the turning radius of the vehicle which helps to park the vehicle by using a very small space. During parking a vehicles driver typically turns the steering wheels through a large angle to achieve a small tuning radius. By counter phase steering of the rear wheels 4WS system realizes a smaller turning radius then is possible with 2 wheel steering (2WS) system. As a result vehicle is turned in small radius at parking.

Junctions

On a cross roads or other junction where roads intersect at 90 degrees or tighter angles counter phase steering of the rear wheels causes the front and rear wheels to follow more o-less path. As a result the vehicle can be turned easily at a function.

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Slippery Surfaces

While steering operation on snow, icy, muddy and other low friction surfaces steering of the rear wheels suppress sideways drift of the vehicles' rear end. As s result the vehicles' direction is easier to control.

V. ADVANTAGES AND DISADVANTAGES

Advantages

There are many advantages of 4WS system. Some are given below

Superior cornering stability

Improved steering response and precision

High speed straight line stability

Improved rapid lane changing maneuvers

Smaller turning radius

Without these advantages there are many more advantages of 4 Wheel Steering System which is very much helpful for driving vehicles.

Disadvantages

Along with many advantages 4 Wheel Steering has some disadvantages too.

Expensive Construction

Constructions of 4WS vehicles are very much expensive. It took huge amount of money to completely make a 4WS vehicle. It needs lots of components to function properly so this also increases the expense.

Complex Mechanism

Mechanism of 4WS is pretty much complex. As there are many electrical parts included in the construction so there is always a chance to get any of the part inactive, thus the system become in operative.

VI. CONCLUSION

The tie rods connect to the track rod. There are a large number of variations of the actual mechanical linkage from direct-link where the pitman arm is connected directly to the track rod, to compound linkages where it is connected to one end of the steering system or the track rod via other rods.

The example here shows a compound link (left). Most of the steering box mechanisms that drive the pitman arm have a 'dead spot' in the centre of the steering where you can turn the steering wheel a slight amount before the front wheels start to turn. This slack can normally be adjusted with a screw mechanism but it can't ever be eliminated. The traditional advantage of these systems is that they give bigger mechanical advantage and thus work well on heavier vehicles. With the advent of power steering, that has become a moot point and the steering system design is now more to do with mechanical design, price and weight. The following are the four basic types of steering box used in pitman arm systems.

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