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Implementation of Four Wheels Steering Using 3-Way Worm Gearbox In An All Terrain Vehicle

Arshit Vashisht, Anand Baghel, Rishi Katara, Pradeep Sharma, Aakash Suran
(Faculty Automobile Engg.)
(Automobile 3rd year)
(Mechanical 3rd year)
(Mechanical 3rd year)
RUSTAM JI INSTITUTE OF TECHNOLOGY

ABSTRACT
This paper represents the use of 3-way worm gearbox in order to implement four-wheel steering in an ALL TERRAIN VEHICLE. The basic theme behind implementation of this gearbox is to reduce turning radius & provide directional stability while manoeuvring

The main characteristic of vehicle moving on road is related to its response to the drivers command and to environmental factors affecting the direction of motion of vehicle. The two basic problems in handling the vehicle are control of vehicle along the desired path and stabilization of the direction of motion of vehicle against external disturbances. The vehicle with best handling characteristics is the vehicle which can always be controlled by the driver. While parking the vehicle and doing sharp turnings the vehicle with two wheel steering cannot be more significant. The two wheel steering system takes large radius of turning and requires more space to take turn. Hence four wheel steering is preferable than two wheel steering systems. A multi-function four wheel steering system could improve directional stability at high speeds, sharp turning performance at low speeds, and parking performance of a vehicle

The turning radius was reduced by 30% in comparison to normal two wheel steering system. The idea of selecting 3-way worm gearbox is to bear robust and rugged steering under critical conditions.

The relation between steer travel and lock angle was established and for same Ackermann % was calculated. In this mechanism the basic work was done to reduce the gear ratio of front wheel & to increase gear ratio of rear ratio according to weight distribution

I. Introduction

As we know that steering system is one of most important part of an automobile that is used to give directional stability to the vehicle.

There are three ways by which a vehicle can be steered comprising of front wheel steering, rear wheel steering and third one is all wheel steering.

The front wheel steering is generally seen in common cars and a little bit of rear wheel steering have also been employed but problem is that both gives a greater turning radius and also not effective in manoeuvring.

	Gear1 (Steering input)	**Gear2 (Front rack)**	**Gear3 (Rear rack)**
No. of teeth	08	06	08
Pitch circle Dia.	24mm	18mm	24mm
Velocity Ratio	-	1:1.33	1:1

So to overcome all such problems the concept of 4WS was implemented.

There are number of ways by which four wheel steering system can be implemented in an ATV such that by using same side linkage mechanism, by using double pinion rack, but the problem is that they all are too costly and not reliable.

So to overcome all these problems a new & fresh mechanism is used and that one includes new style steering gear box under which 3-way worm gearswere used of namely as one for front & second for rear output & third for driver input.

In this gear box all the gears are arranged in a systematic manner (fig) so that meshing of gears can take place all the time while in use.

For this worm gears were given preference on other gears because of their meshing ability & low slipping and low chattering sound.Its high turning ratio would be advantageous in manoeuvring the vehicle in tight turns.

For test set up of gearbox two centrally mounted rack & pinion steering gears (Tata Nano)

Were used. The front rack is coupled with front gear of gearbox & rear rack is also connected to gearbox via steering shaft.

At the end of steering shafts Universal joints are provide to facilitate the torque transfer in case of rack & gearbox are not co-axial.

The drive in the worm gearbox was given with the help steering wheel fitted with steering column to gearbox. On turning the steering wheel, the drive gear rotates and along with it, two driven gears also rotates and hence pinion of both rack also rotates.

II. Calculations Regarding 3-Way Worm Gearbox

A lot of brainstorming was carried out while deciding the basic parameters of gears such that:-

1. No. of teeth in all gears
2. Pitch diameter
3. Module
4. Depth of teeth

After analysing the behaviour of vehicle in two wheel steering it was found that critical parameters are total weight of vehicle, weight distribution, wheel base and wheel track.

III. Theorotical Calculations

Generally Tata Nano rack has a steering gear ratio of 15.1:1 and due to such large ratio, number of lock to lock to turns also increases and this aids to fatigue to driver but by employing 3-way worm gearbox the output gear ratio can be achieved as desired.

This can be done as follows:-

Let no. of teeth in front gear (N_1) =6

Let no. of teeth in rear gear (N_2) =8

Let no. of teeth in driver gear (N_3) =8

Hence gear reduction will take place as

= No. of teeth in driven gear/no. of teeth in driver gear

Now for the front rack

Gear reduction will be= (N_1)/ (N_3) =6/8

=0.75

And hence final gear ratio will be,

=0.75*15.1

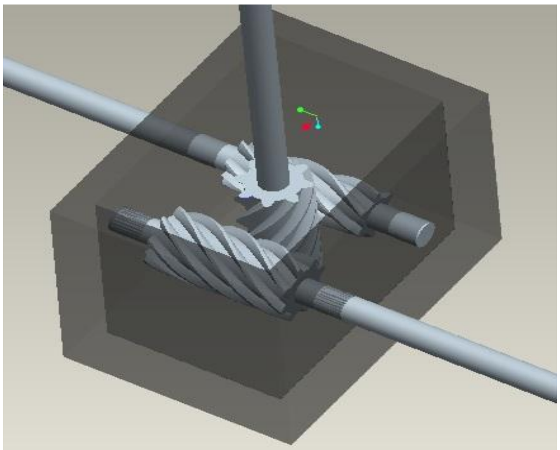
=11.325

And by following the same procedure,

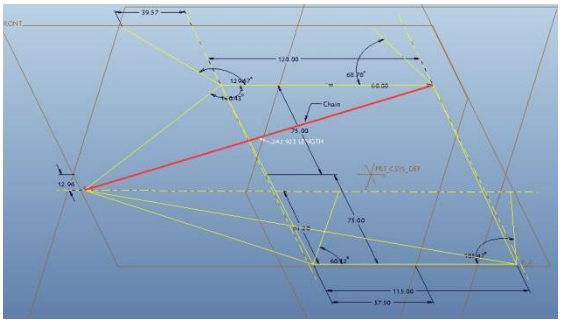
Final gear ratio of rear rack will be,

=15.1

Hence from calculations we can see that how a single gearbox can be used to vary the gear ratio of two racks.



ISOMETRIC VIEW GEARBOX



SKETCH OF FOUR WHEELS STEERING GEOMETRY IN PRO-E 5.0

3-D MODEL OF FOUR WHEELS STEERING IN PRO-E 5.0

IV. Reduction Of Turning Radii Of An Atv

The major problem associated with the two wheel steering system is that its turning radius goes higher but with the implementation of 3-way worm gearbox this problem can be mitigated to about 30%.

By using opposed Ackermann geometry means front wheels & rear wheels are in opposite direction to each other turning radius is also reduced along with increment in lane changing and cornering ability of an ATV.

V. Turning Radii Calculation Of A Four Wheel Sterred Vehicle

LET DATA USED:-Wheel base (L) =148cm,
(Front Track)$w_f = 136cm$,
(Rear Track)w_r=134cm,
c_1+c_2=L=148cm,
a_1=98.68cm,
a_2=49.32cm
Steering rack ratio=front rack ratio=11.325:1
= rear rack ratio=15.1:1

CALCULATION OF LOCK ANGLES FOR FRONT& REAR WHEELS

Front inner lock angle (δ_{if})= (total no. of steering wheel rotation*360)/front rack ratio
= (1.25*360)/11.325
=39.57deg

Rear inner lock angle(δ_{ir})= (total no. of steering wheel rotation*360)/rear rack ratio
= (1.25*360)/15.1
=29.68deg

Tanδ_{if}=c_1/ (R_1-w_f)…………………… (1)
Tanδ_{of}=c_1/(R_1+w_f)…………………..(2)
Tanδ_{ir}=c_2/(R_1-w_r)……………………(3)
Tanδ_{or}=c_2/($R_{1+}w_r$)………………….. (4)

On putting the value of δ_{if} and δ_{ir} in equation (1) and (2) and using $c_1 + c_2$=L we getδ_{of}=21.56deg and δ_{or}=15.72deg

Turning radii calculation

R_{fo}= {Lcosθ_{ro}-sin $\theta_{ro}(b_r - b_f)/2\}/\sin(\theta_{fo} + \theta_{ro})$
R_{fo}= 235.64 cm

$$R_{ro} = \{Lcos\theta_{fo} + sin\theta_{fo}(b_{r-}b_f)/2\} / \sin(\theta_{fo} + \theta_{ro})$$

R_{ro}= 226.63 cm

$$R_{fi=}\{Lcos\theta_{ri} + sin\theta_{ri}(b_r - b_f)/2\}/\sin(\theta_{fi} + \theta_{ri})$$

R_{fi}= 136.97 cm

$$R_{ri} = \{Lcos\theta_{fi} - \sin\theta_{fi}(b_r b_f)/2\}/\sin(\theta_{fi} + \theta_{ri})$$

R_{ri}= 122.67 cm

Calculation of Ackermann percentage

$$\delta_{inside\ 100} = TAN^{-1}\left(\frac{WB}{\frac{WB}{TAN(\delta_{outside})} - Tr}\right) - \delta_{outside}$$

WB = Wheelbase
Tr = Front Track
$\delta_{inside\ 100}$= Inside Steer for 100% Ackerman

=10.25deg

$$\%\ Ackerman = \frac{\delta_{inside} - \delta_{outside}}{\delta_{inside\ 100\%\ Ackerman}} \times 100$$

δ_{inside} = Inside Ste
$\delta_{outside}$ = Outside St

=175.70%

Calculation for rear as similar to above formula we get

$\boldsymbol{\delta_{inside100}}$**=4.97**
Ackerman %=280.88
On subtracting Ackermann% of front from rear we get overall Ackermann %= 105.18%

Ackerman angle calculation:-
Tanα= (sinø-sin□)/(cosø+cos□-2)
Outer wheel lock angle (ø),Inner lock angle (□)
For front axle
α = 41.00 deg
For rear axle
α = 53.13 deg
So ackermann angle for all wheel steer = α_{rear} - α_{front} = 53.13 – 41.00 = 12.13 deg

CRITICAL TURNING VELOCITY (VC)

VC= $\sqrt{\mu g r}$
VC=$\sqrt{0.7 * 9.8 * 2.35}$
VC= 4.015 m/s or 14.454 km/hr

VI. Turning Radius Calculation For Two Wheel Steering

Turning radius calculation
R (min) =l/tan□
=148/ tan(39.57)
=179.17cm

$R(\boldsymbol{max})^2 = \{\boldsymbol{R}(\boldsymbol{min}) + \boldsymbol{w}\}^2 + \boldsymbol{L}^2$
$= \{\mathbf{179.17 + 136}\}^2 + \mathbf{148}^2$
$\boldsymbol{R_{max}}$ **=348.189cm**

VII. Conclusion

The conclusion of this paper is that using a 3-way worm gearbox reduces turning radius of an ATV efficiently and also aids to enhance the stability of vehicle because of its mounting in cockpit.
It is cheaper and easily serviceable and can be manufactured at large scale.
The idea behind four wheel steering is that a vehicle requires less driver input for any steering maneuver if all four wheels are steered in the vehicle. As with two wheel steer vehicles, tire grip holds the four wheels on the road.

So resultof this paper can be shown in following points and table

Four-wheel steering with the use of 3-way worm gearbox has following merits.
1. Superior cornering stability.
2. Improved steering responsiveness and precision.
3. High speed straight line stability.
4. Notable improvement in rapid lane changing maneuvers.
5. Smaller turning radius and tight space maneuverability at low speed.

6. Relative wheel angles and their control.

Turning radius	**Two wheel steer**	**Four wheel steer**
By Calculation	3.48m	2.35m
By Experiment	3.60m	2.43m

VIII. References

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