Design and Optimization of Steering System

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Abstract - *The objective of presented work is to acquire maximum Ackerman angles in steering system. The dissertation contains design and manufacturing of steering system. Entire work was to be completed by following Formula Bharat restrictions and design requirements. Formula style vehicle requires utmost effort on steering system an account of driving it at high speed and accomplishing optimal corning at low speed. Ackerman steering system was to be selected from the various steering system by analyzing inclination of outside and inside wheel at different speeds. Ackerman steering system usually achieves around 25^0 inclination at inside wheel and 18^0 outside wheel, it governs by steering geometry and steering mechanism from the steering wheel to vehicle wheels. Optimization of steering system is achieved by designing and manufacturing whole mechanism at optimum level.*

Key Words: Ackerman Steering Geometry, Motion transmission, Rack and Pinion Housing.

1. INTRODUCTION

Steering system in vehicle illustrates direction and corning at required angle. Steering system is a group of linkages that transmit the movement of steering wheel of the steering wheel to the front, and sometimes the rear, wheels. The primary purpose of the steering system is to allow the driver to guide the vehicle. When a vehicle is being driven straight ahead, the steering system must keep it from wandering without requiring the driver to make constant corrections.

Entire Ackerman steering system is to be designed and manufactured by following Formula Bharat restrictions and design requirements. According to that rules power steering system is not allowed to use for transmitting motion from steering wheel to tie-rods. In other hand Ackerman steering compensates all necessities, so it is chosen among various systems.

Calculations

Force calculations

Weight of the car = 330kg

Now, considering the weight distribution as 40% on front side and as engine assembled at rear portion, so 60% weight at that portion.

For this vehicle, for the front-wheel steering system considering 40% weight of the body and also further calculations based on that.

Weight at front side
= (330*40)/100
= 132kg
Now weight on each wheel = 132/2
=66 kg

Due to this weight, force generated is in vertical (upward) direction and is given by,
=66*9.81 =647.46N (Normal Reaction)

Now, there is presence of suspension system to absorb this load, but for the safe side, we let the force acting on the tie-rod as a 647.46N in a static condition.

As we know that F=μ*Normal Reaction So, for the static condition μ=1.0 F=647.46 N

So, more amount of the force must be transmitted by pinion to the rack so, moment generated at the pinion is given by,

M=F* (Radius) =647.46 * 9.00 =5827.14Nmm

Now, similar to that moment, force needs to apply on steering wheel can be calculated,

Moment generated= (Force)*(Steering wheel Radius) 5827.14=Force*115

Force required = 50.67 N

Stress calculations

Stress generated on Tie-rod – T/J=Ʈ/R
Ʈ = (T*R)/J (5827.14*7)/ ((∏/32)*(D^4 - d^4)) Here, D=14mm & d=10mm
(Here tie-rod is a hollow cylinder)
So by putting above value getting stress,
Ʈ=14.628MPa

Module Calculation:

There are following two methods for finding-out module for desired loading conditions:

1 .Estimation of module based on BENDING STRENGTH
2. Estimation of module based on WEAR STRENGTH

Now, by using 1st theory we can find module by following,

P (t) = m*b*б (b)*Y

Where, P(t)= load to be Transmitted

m = module of gear

b = Face-width of the gear tooth (14.98mm)

б(b)= Bending Stress of the Material

Y= Lewi's constant (Its value is 0.32 for No. of Teeth=12)

P(t) =110*cos (20^0) =103.36 N

б(b) = M*y/I

=((P(t)*h)*(t/2))/((b*t^3)/12),

h= height of the tooth

=Addendum + Dedendum

=1.5 + 1.875

=3.375mm

t = 2.356mm (tooth thickness)

= ((103.36*3.375)*(2.356/2)) / ((14.98*2.356^3)/12);

=25.172 N/mm^2;

Now, by putting above values into main equation we get, m = P (t) / (b*б (b)*Y); 103.36 / (14.98*25.172*0.32); m= 1.0

Now, design is made of final component, by considering Module (m) = 1.50.

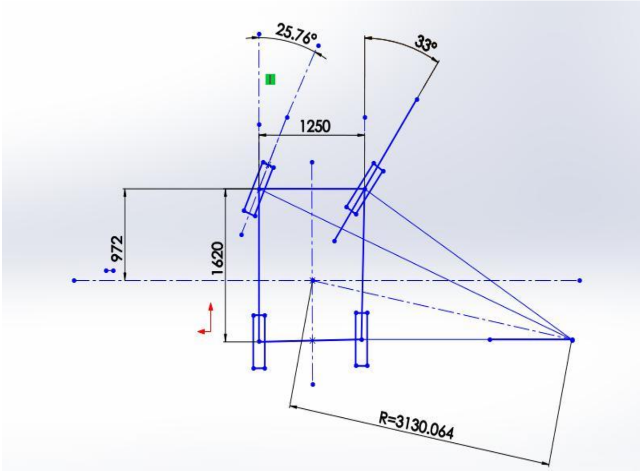
Turning radius:

tanβ= L / R –D/2 ,

Where L= track length = 1250 mm

D= wheel base= 1620 mm

β= Inner angle = 33^0



Design of Ackerman steering geometry

By putting all these values we got, R= 3.119m

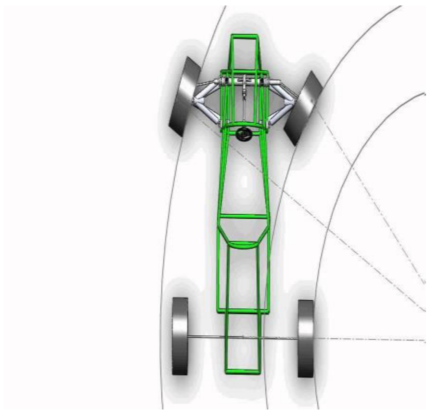
Steering Ratio:

Here, steering ratio shows the ratio of steering wheel rotation to the Ackerman angle rotation. So,

Ratio = Steering wheel rotation / Ackerman Angle rotation
= 90 / 33
= 2.72

Steering Geometry:

When a vehicle travels round a bend, the inside wheel must follow a tighter curve than the outside wheel to achieve this, the geometry of the steering must be arranged to turn the inside wheel through a larger angle than the outside wheel. The 'Ackerman' steering geometry provides a simple solution to this problem. Shown is a representation of true Ackerman.



Formula 3 car top view

Ackerman steering geometry has 1620mm wheelbase and 1250mm track length for formula3 style vehicle. To acquire determined Ackerman geometry, outside angle of vehicle wheel must be larger than inside one. In addition to accomplish this criteria inside angle has been fixed 33^0 for getting optimal corning, consequently outside angle has been achieved 25.76^0 in SolidWorks 2013 and also calculated by, $\cos\acute{\alpha}+\cos\beta=L/D$

In steering geometry, L and D illustrates wheelbase and track length respectively, $\acute{\alpha}$ and β represents outside and inside angle respectively. Turning radius is also elucidates vehicle corning. In SolidWorks 2013, It Is measured from the center of gravity to the point of intersection of perpendiculars of front wheel centerlines. It has been measured 3130mm. Turning Radius (R) is calculated theoretically as,

$\tan\alpha = L / R + D/2$ OR $\tan\beta = L/R - D/2$

Motion transmission:

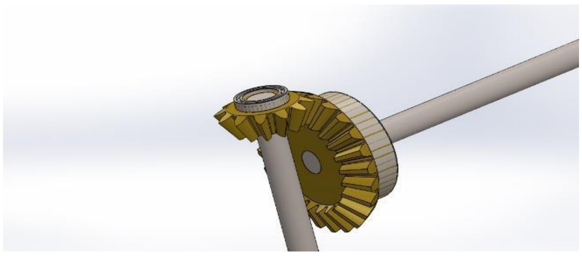
Universal joint with shafts

Steering system has motion transmission from the steering wheel to vehicle wheels. Entire motion transmission is summation of two transmission as intermediate transmission and rack–Pinion transmission. In Formula 3 car vehicle, intermediate transmission can be achieved by providing universal joint steering wheel shaft and pinion shaft. This universal joint has been used for transmission in Formula style vehicle.

Universal joint

While using universal joint, each joint requires individual support of bearing, it openly increases system's overall weight. Manufacturing cost of universal joint is too much higher than the other alternatives. There were also generation of wear while rotating the shafts which are connected to the both ends of universal joint.

This condition frequently occurs when joint is not appropriately lubricated. Other alternative to transmit motion from steering wheel to vehicle wheel is bevel gears. Transmission through bevel gears is more efficient than universal joint. Objective of the steering system is to attain maximum angle of inside wheel by minimum rotating steering wheel.



Design of Bevel transmission

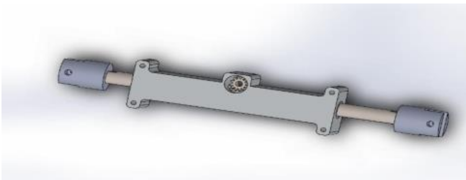
Only single transmission ratio (1:1) can be achieved at both the end of universal joints. In flip side bevel gears can achieve multiple transmission ratio as 1:1, 1:2, 1:3, etc. Due to this phenomenon transmission rotation can be rise from the steering wheel to vehicle wheels. Bevel gear of 1:2 ratio has been used to increase transmission from steering wheel to pinion. When single rotation is given to steering wheel shaft by steering wheel, pinion shaft achieves double rotation and pinion moves on rack.

Actual model of Bevel Gears

Bevel gear of 1:2 ratio has been designed in SolidWorks 2013. Bevel gear has Pitch circle diameter of 24mm and 12 teeth (module 2). While Bevel pinion is designed with half dimension of PCD and number of teeth to get transmission of 1:2 ratio.

Rack and Pinion Housing:

Rack and pinion has been designed to get accurate motion transmission from the bevel gear to pinion. SS EN9 material has been used to manufacture pinion with module of 1.5 and Pitch circle diameter of 18mm and for rack SS410 material has been used with length of 340mm. Rack and pinion transmission has achieved inside the housing. It is manufactured as per the dimension of rack and pinion.



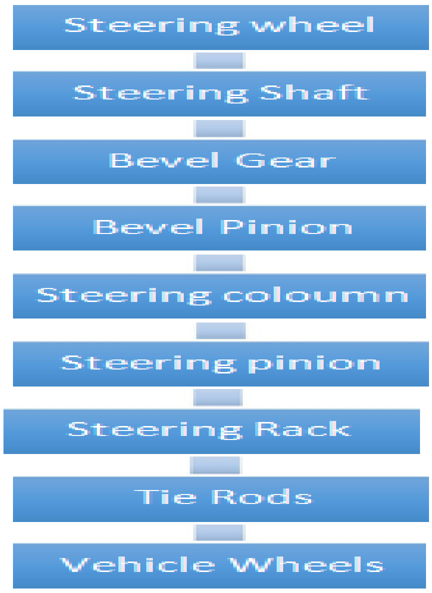
Design of Rack Pinion Housing

Actual model of Housing

120mm length has teeth on rack and acquired lock to lock situation by rotation of pinion on rack as, 2Πr where r illustrates radius of pinion. It has magnitude of 56.52mm rack travel. Lock to lock situation demonstrates end to end rotation

Steering assembly

Of pinion on rack. As Steering wheel rotates 90^0, inside wheel has achieved 33^0 and outside wheel has achieved nearly 26^0 as per the design geometry of Ackerman steering system. Consequently when steering wheel is rotated 90^0(complete rotation) steering wheel shaft rotates 90^0 and bevel gear connected with that shaft also rotates at same rotation so bevel pinion gets twice rotation as 180^0 because of the transmission ratio 1:2. Pinion of rack-pinion housing received same rotation and moves on rack in respected direction and travel distance up to half of its circumference (Πr). This travel of Πr on rack forces tie rods which are connected to knuckle of wheel. Thus wheels of vehicle attains 33^0 inside and 25^0 outside way.



Conclusion:

Ackerman steering geometry can achieve more inside angle than Anti Ackerman steering geometry. In Ackerman steering geometry, motion transmission through bevel gears is more efficient than transmission through universal joint because universal joint has single transmission ratio at its both ends.

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