Design of Steering Gear System in Automobiles.

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CHAPTER-1

INTRODUCTION

1.INTRODUCTION

Currently, the most advanced cars on the planet are the formula one car and thus the steering are as much advanced as the car is. Modern steering wheels have a lot of functions with a lot of buttons fitted on them. Over the years there have been a lot of changes. The current steering wheel cost about Ksh.5million and with carbon fibre construction which makes it weighs at about 1.3kgs.

The very first vehicles hardly had any steering wheel and were steered by some long poles called tillers. With advancements in technology, steering wheels were invented. By this time formula one cars were invented, the steering wheel had the following characteristics:

• The steering was from normal road cars and it was made of wood. Due to this, drivers mainly wore gloves during driving to avoid getting wooden splinters in their hands.

• The steering wheels had a large diameter to reduce the effort in turning Power steering had not been invented yet and thus it was very difficult to make the car turn.

Since then, the vehicles have become so advanced to the point that virtually every part of the car can be monitored on the steering wheel. The incredible design in this form of car has motivated mechanical students all around the world to take part in an international competition organized by SAE. Nowadays, Formula Student is the most prestigious competition of its kind. This competition seeks to bring students from 120 universities round the world to design, manufacture, develop and compete with a car, like a small formula one team. The aim of this challenge is to help young talented engineers to develop in the professional world.

When we observe a car making a turn, in order to do the turn comfortably, the wheel that is in the exterior side of the turn covers a larger distance. On the contrary the rear wheels in any time of the turn are parallels. This causes a problem where the outer wheels cover a larger distance than the inner wheels. This will cause skidding of the car. Skidding is reduced in the rear wheels with the presence of a differential. Although there is a differential, the skidding effect will still be felt if the car made a turn at very high speed.

This effect would have been solved if the formula one car had four-wheel drive which would also add to the car grip, but the four-wheel drive is discouraged due to the weight it adds up to the car. This weight reduces its chances of winning races. In order to counter-act this problem, we use the Ackerman principle.

This principal involved the geometrical solution to this, for which all wheels were 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.

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship or Boat) or vehicle to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide steering column, which may contain universal joints, to allow it to deviate somewhat from a straight line.
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.

The steering system acts a significant role of making car convenient to handle and enhance the vehicle stability. In the past one hundred years, the development of steering system has experienced many stages, and the Steer-by-Wire system (SBW) is the newest technology of steering system for passenger cars. But the Steer-by-Wire system has not yet accepted by public consumers and permitted by state regulations, in consideration of the reliability and safety of the system.

The steering system of a vehicle allows the driver to control the direction of the vehicle through a system of gears and linkages that connects the steering wheel with the front wheels. Steering Systems - Introduction The steering system must perform these functions:

• Change direction of vehicle

• Provide a degree of 'feel' of the road for the driver

• Not transmit excessive shock back to the driver due to an uneven road

• Not cause excessive tyre wear.

Early vehicles used manual steering linkage system, manual steering boxes or manual racks. Later systems used the benefits of hydraulic fluid systems to greatly improve the steering performance. Today, we now have fully electronically controlled steering systems for greater and smoother performance and manoeuvrability.

When turning a corner, the driver turns a steering wheel. This turning motion is transferred to the front road wheels. The direction the front wheels point is the direction the car will travel, so long as the wheels do not lose grip.

Active Front Steering (AFS) is a newly technology for passenger cars developed by BMW, that implements an electronically controlled superposition of an angle to the hand steering wheel angle that is prescribed by the driver. However, the permanent mechanical connection between steering wheel and road wheels remains. AFS could adjust the vehicle performance by means of intervening the road wheel angle in condition of the driver have top priority, which avoid the people's concerns about the Steer-by-Wire system.

A lot of studies about the active steering system are carried out all over the world. But most of the studies focus on the stability of vehicle, which apply AFS, as in. As a basic function of active steering system, the driver will experience the variable steering gear ratio function at first, and perceive the improvement of steering portability. AFS enables continuous and situation dependent variation of the steering ratio according to the vehicle's motion state, therefore AFS improves the manoeuvrability of the vehicle at low speed and the stability at high speed. The performances of stability improvement with active steering system depend upon the quality of variation of the steering ratio to a certain extent. Thence, it is significant to investigate the variable steering gear ratio 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 (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. [1]

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. [1]

Steering System

The design and type of the steering rack depends on the system chosen. The steering systems used are divided into:

a) Power assisted
b) Manual steering systems

Each is designed to help the driver to turn easily for optimal performance with different configuration of the vehicle. The type of steering system suitable for our light weight and simple design will only include the manual steering system due to cost and complexity factors.

Manual Steering Systems

The manual steering systems are used on light weighted vehicles, or vehicles which have the biggest distribution of mass on the rear wheels and can be easily turned with manual steering at low speed. The systems are fast and accurate and it provides a reliable design. [2]

However, it will become more difficult to handle the vehicle at low speed if wider tires are used or more weight is distributed to the front wheels. These concerns playa big role when analysing if manual steering should be used. [2]

The manual steering system incorporates:
• Steering wheel and column
• A manual gear box and pitman arm or a rack and pinion assembly

• Linkages, steering knuckles and ball joints
• Wheel spindle assemblies

There are different types of manual steering gear systems:
a) Worm and roller
b) Worm and sector
c) Worm and nut
d) Cam and lever
e) Rack and pinion

a) Worm and sector

The manual worm and sector assembly uses a steering shaft with a three-turn worm gear supported and straddled by ball bearing assemblies. In operation, a turn of the steering wheel causes the worm gear to rotate the sector and the pitman arm shaft and the movement is transmitted through the steering train to the wheel spindles. [3]

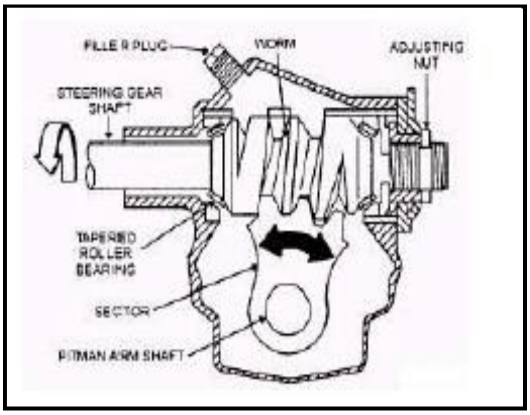

Figure 1.1: Worm and sector steering gear system (http://www.tpub.com/basae/213.htm)

b) Worm and Roller

The manual worm and roller steering gear has a three-turn worm gear at the lower end of the steering shaft. Instead of a sector on the pitman arm shaft, the gear box has a roller assembly (usually with two roller teeth) that engages the worm gear. The assembly is mounted on anti-frictional bearings. When the roller teeth follow the worm, the rotary motion is transmitted to the pitman arm shaft, pitman arm and into the steering linkage. [7]

The worm has an hourglass shape for variable steering ratio and better contact for the worm and roller. The variable steering ratio will result that the wheels turns faster at some positions than others. This will provide more steering control at the centre of the worm, and more rapid steering as the wheels are turned. [7]

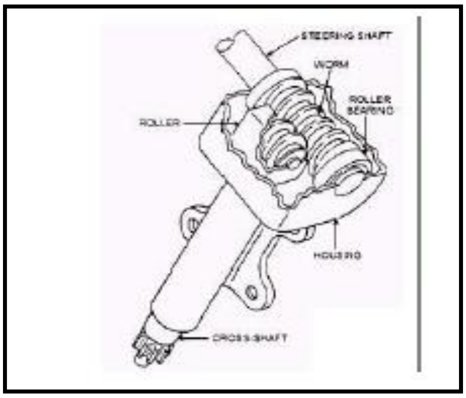

Figure 1.2: Worm and roller steering gear system (http://www.tpub.com/basae/213.htm)

c) Worm and Nut

The worm and nut steering gear comes in different combinations where there circulating ball is the most common type. The recirculation ball combination offers the connection of the nut on a row of balls on the worm gear to reduce friction. Ball guides returns the balls as the nut moves up and down. The ball nut is shaped to fit the sector gear. [7]

When the steering wheel is turned, the steering shaft rotates along with the worm gear fitted at the end of it. The recirculation balls starts to move, and this moves the ball nut up and down along the worm. This turns the pitman arm. [7]

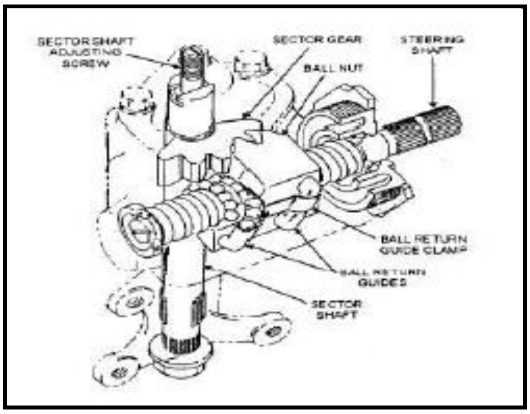

Figure 1.3: Worm and nut steering gear system (http://www.tpub.com/basae/213.htm)

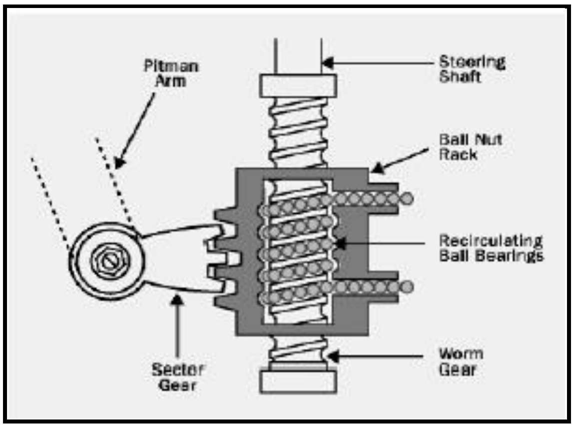

Figure 1.4: Dissected worm and nut steering gear system
(http://auto.howstuffworks.com/steering3.htm)

d) Cam and Lever

In the cam and lever gear, two studs are connected on the lever and engage the cam. As the steering wheel is turned, the steering shaft will rotate and move the studs back and forth which move the lever back and forth. This will cause a rotation in the pitman arm. The lever is increased in angle compared to the cam, which will result in a more rapid move of the lever as it nears the ends, as in the worm and nut gear. [7]

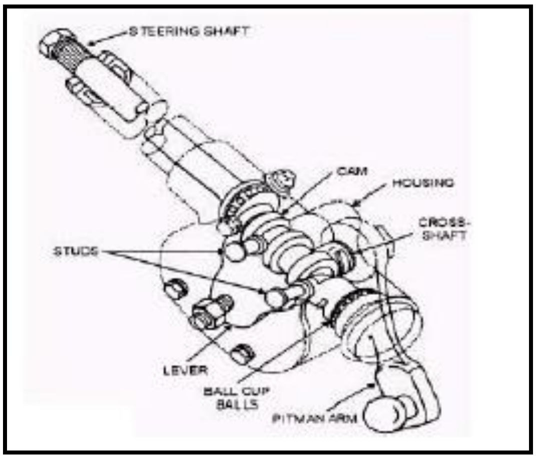

Figure 1.5: Cam and lever steering gear system (http://www.tpub.com/basae/214.htm)

e) Rack and pinion

A typical rack and pinion steering gear assembly consists of a pinion shaft and bearing assembly, rack gear, gear housing, two tie rod assemblies, an adjuster assembly, dust boots and boot clamps, and grommet mountings and bolts. When the steering wheel is turned, this manual movement is relayed to the steering shaft and shaft joint, and then to the pinion shaft. Since the pinion teeth mesh with the teeth on the rack gear, the rotary motion is changed to transverse movement of the rack gear. The tie rods and tie rod ends then transmit this movement to the steering knuckles and wheels. [7]

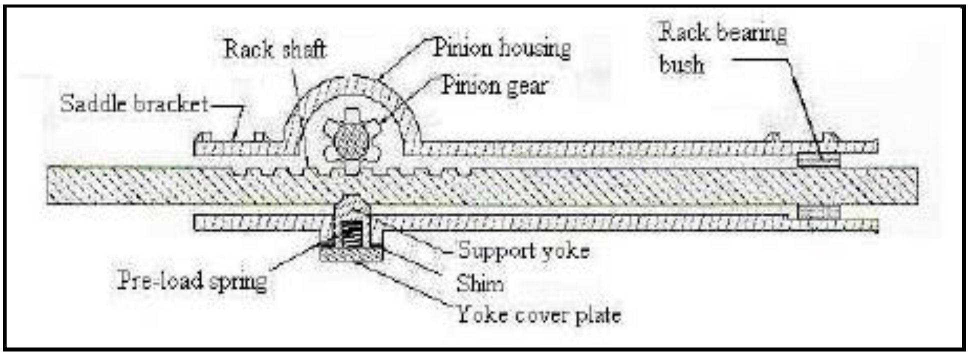

Figure 1.6: Rack and pinion steering gear system
(http://what-when-how.com/automobile/steering-components-automobile/)

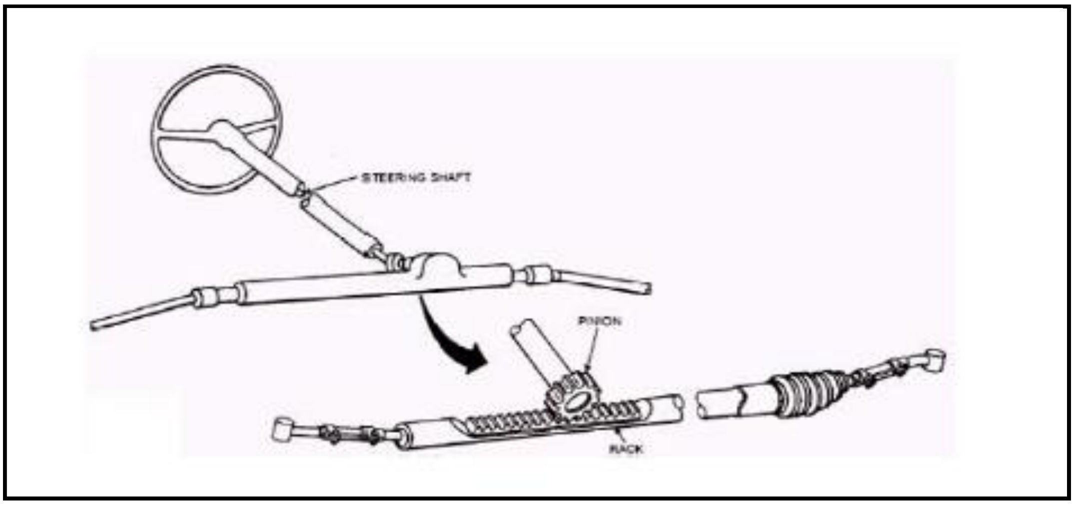

Figure 1.7: Illustrative positioning of the rack and pinion gear system
(http://www.tpub.com/basae/214.htm)

ACKERMAN STEERING

The people who designed horse drawn buggies and carriages realized this fact and came up with the Ackerman steering principle. All that this means is that the extended axes of the steering arms meet at the centre of the rear axle and, when the vehicle is following a curved path, the inside front wheel will be steered to greater degree than the outside front, so that both can follow their individual radii without skidding. No single intersection point will result in true Ackerman steering over the whole range, but by moving the intersect point in the longitudinal plane, you can come close in the normal range of steering angles.

This is neat for a coach and four showing off in Hyde Park but the minute we put pneumatic tires on our racing car and place Fangio in the seat, the whole picture changes due to slip angles. We have already known that in order for the vehicle to change direction, each of the four' wheels must assume some slip angle and that the side force generated by any tire must act in the direction perpendicular to the rolling path of that tire. This modifies the Ackerman picture considerably as shown in Figure.

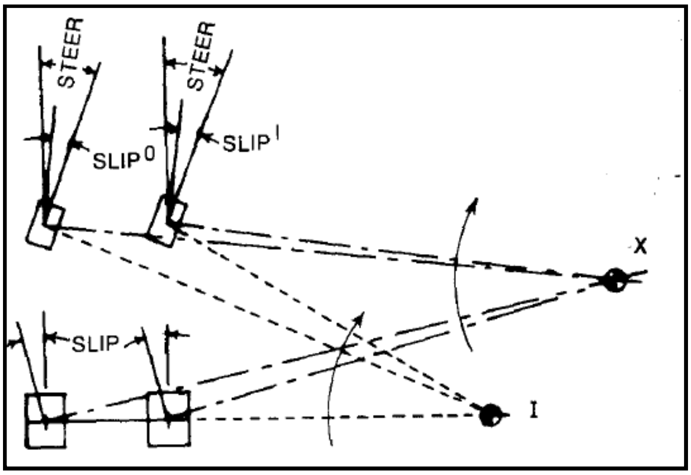

Fig 1.8: The Ackerman picture modified by slip angle.

Because the rear wheels have developed a slip angle, the instantaneous centre of curvature has moved from position I to position X. If we want the front tire slip angles to be similar to those of the rear tires, and similar to each other, then the front wheels are going to end up more nearly parallel to each other than in the Ackerman setup. In addition, lateral force transfer during cornering assures us that the outside front tire is going to run at a higher slip angle than the inside front and will do almost all of the steering. Under these conditions, if the inside front is at a greater steering angle, it will scrub across the race track. For these reasons, racing cars do not employ as much Ackerman correction as street cars. Some designers have even employed "anti-Ackerman" steering geometry in an effort to even out the front tire slip angles.

CONVENTIONAL STEERING SYSTEM

In that steering system, only the front wheels are steered towards right or left According to the requirement because of at rear their dead axle is present.

FOUR WHEEL STEERING SYSTEM

In that steering system, the all four wheels are to be steered according to the steer perform to drive towards left or right. Four-wheel steering, 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. 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.

In most active four wheel steering system, the rear wheels are steered by a computer and actuators, the rear wheels generally cannot turn as far as the front wheels. Some systems including Delphi’s Quadra steer and the system in Honda’s Prelude line allow the rear wheels to be steered in the opposite direction as the front wheels during low speeds. This allows the vehicle to turn in a significantly smaller radius sometimes critical for large tucks or tractors and vehicles with trailers.

In this paper a virtual prototype of rack and pinion assembly with complete SOLIDWORKS geometry is proposed to enhance and facilitate steering response by varying the different parameters employed during its design and manufacturing. It is important to know how the different aspects like steering ratio, pinion diameter, rack length etc. Govern the working of the mechanism. The possibility of decreasing lock to lock steering degree has motivated us to work upon this system. According to Ackermann Steering geometry, the outer wheels moves faster than the inner wheels, therefore, the equation for correct steering is:

$$\text{Cot } \Phi - \text{Cot } \theta = b/l$$

In the image shown below,
Φ = outer wheel angle
θ = inner wheel angle
b = track width

L = wheelbase
α = Ackermann angle

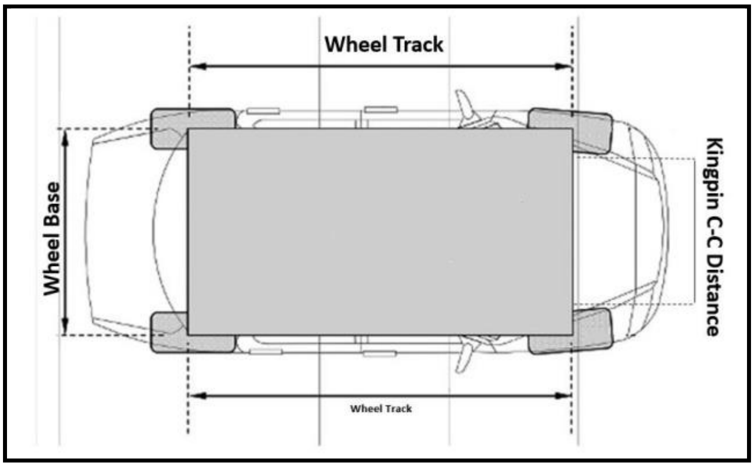

Fig.1.9 Wheel Track, Wheel Base and Kingpin C-C Distance

The intention of Ackermann geometry is to prevent the tyres from slipping outwards when the wheels follows around a curve while taking a turn. The solution for this is that all wheels to have their axles settled as radii of circles with a common centre point. Since the rear wheels are fixed, this centre point must lie on a line extended from the rear axle. So we need to intersect the front axle to this line at the common centre point. While steering, the inner wheel angle is greater than outer wheel angle. So for obtaining different results we need to vary the parameters in order to obtain desired steering geometry.

1.1 PROBLEM STATEMENT

ESVC is a student design competition sponsored by the ISIE. Teams design, build, and compete with a small open wheel solar car in an international competition among engineering schools. The solar cars are evaluated on their dynamic performance, design process and solutions, and business concerns such as cost and marketability. In this highly competitive field teams must build an extremely agile and lightweight vehicle to succeed in the competition's tight autocross courses. Four-wheel steering is an advanced method of improving a car’s handling capabilities and adding additional parameters for tuning the car’s dynamic profile. The problem is to design a four-wheel steering system to go on the Electric Solar Vehicle Championship.

In conventional steering system we use the Ackermann geometry this is the arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheel on the inside and outside of a turn needing to trace out circles of different radii.

In Anti-Ackermann geometry at low steering ratio and at high speed handling capacity is low to eliminate this drawback we use the Ackermann geometry in Ackermann geometry high speed handling increases and reduce the condition of over-steer and the vehicle handling capacity increases.

1.2 OBJECTIVES

The function of the steering system is clearly to afford the driver directional control of the vehicle, and to provide this control with sufficient accuracy to choose the best course around corners, to avoid other vehicles and stationary obstructions, and to manoeuvre the car efficiently at low speed. Determining the influencing factor that affects the steering effort. The following parameters need to be designed like, `

1.Design of Steering arm angle.

2. Design Steering arm length.

3. Optimize Rack Position and placement of rack.

4. Optimize Steering Effort These factor should be design according to wheel base and wheel track of the vehicle.

5. To study various wheel alignment related issues.

6. To understand the steering system in an automobile.

7. To study the components of steering systems and their configurations.

1.3 SCOPE

An innovative feature of this steering linkage design is its ability to drive all four Wheels using a single steering actuator. Its successful implementation will allow for the development of a four-wheel, steered power base with maximum manoeuvrability, uncompromised static stability, front- and rear-wheel tracking, and optimum obstacle climbing capability.

The advanced system of “Four wheel steering” will work electronically with the help or microprocessors.

The system will utilize an on board computer to control and direct the turning left and right of the rear wheels.

One of the big challenges in moving to steer-by-wire is, Seeger said, communications. That's right: The internal network. Because a steer-by-wire system has no mechanical connection between the steering wheel and the front wheels, instead of creating a system that is fail-safe, one that is fault-tolerant is needed: If something goes wrong, the system still operates. This means data redundancy is the system. "Rather than the CAN communications that we used today, we need something like Flex Ray to allow high-speed communications between the components." So there is a bandwidth issue. And, of course, higher power requirements. "Today with electric power steering, the driver inputs some torque and we multiply it. With steer-by-wire, 100% of the effort to steer the vehicle has to come from the electric motor."

Interestingly, Delphi actually had a steer-by-wire system in the market. The model year 2002 GMC Sierra Denali and the 2003 Chevy Silverado and GMC Sierra were offered with Quadra steer four-wheel steering. The rear wheels were essentially a steer-by-wire system.

Looking ahead, Seeger suggested that the first car to use a full steer-by-wire system will be a luxury model-quite possibly a large sedan, with plenty of electric amenities, which would need, yes, higher power. Which will come...no one wants to venture a guess. Call it "the future."

1.4 METHEDOLOGY

The design starts with car geometry these are track width and wheel base.

Then the Ackermann angle is calculated by intersecting the lines from ends of pivot to centre of rear axle. this can be done in any software like creo or solid works. I am attaching a photo for clear understanding

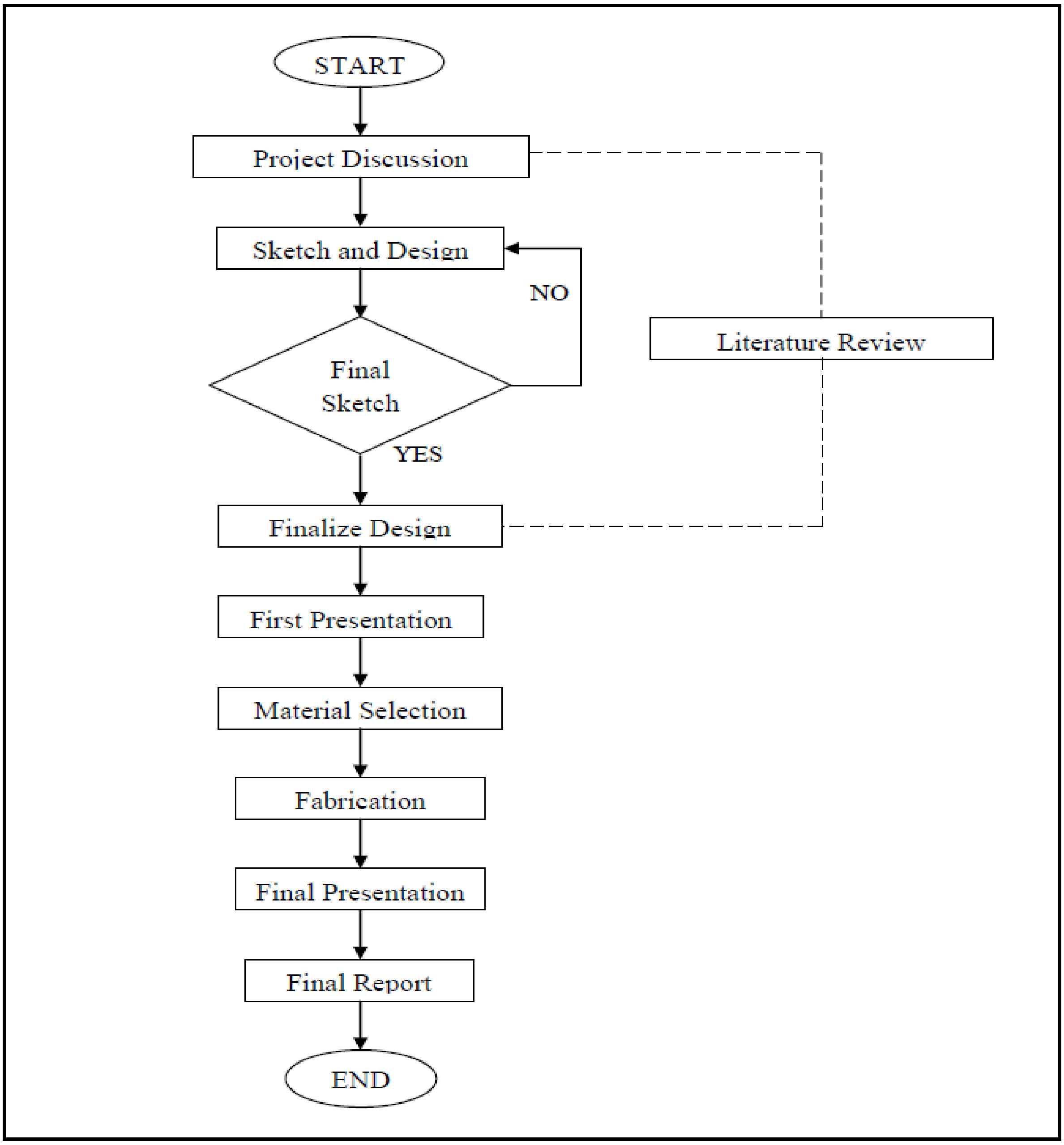

Figure 1.9: Project Flow Chart

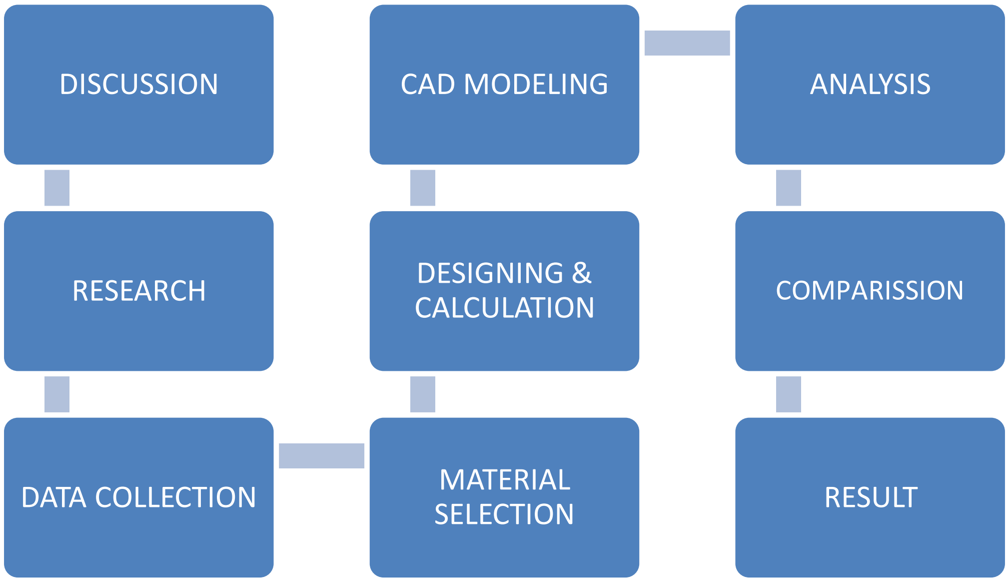

Fig.1.10 Flow Chart of Methodology

Components:

1. Steering wheel handles the steering operation.

2. Steering column joins the steering wheel and the steering gears.

3. Steering gears Convert the steering torque and rotational deflection from the steering wheel, transmit them to the wheel through the steering linkage, and make the vehicle turn.

4. Steering linkage a steering linkage is a combination of the rods and arms that transmit the movement of the steering gear to the left and right front wheels. Also, there are two types of steering.

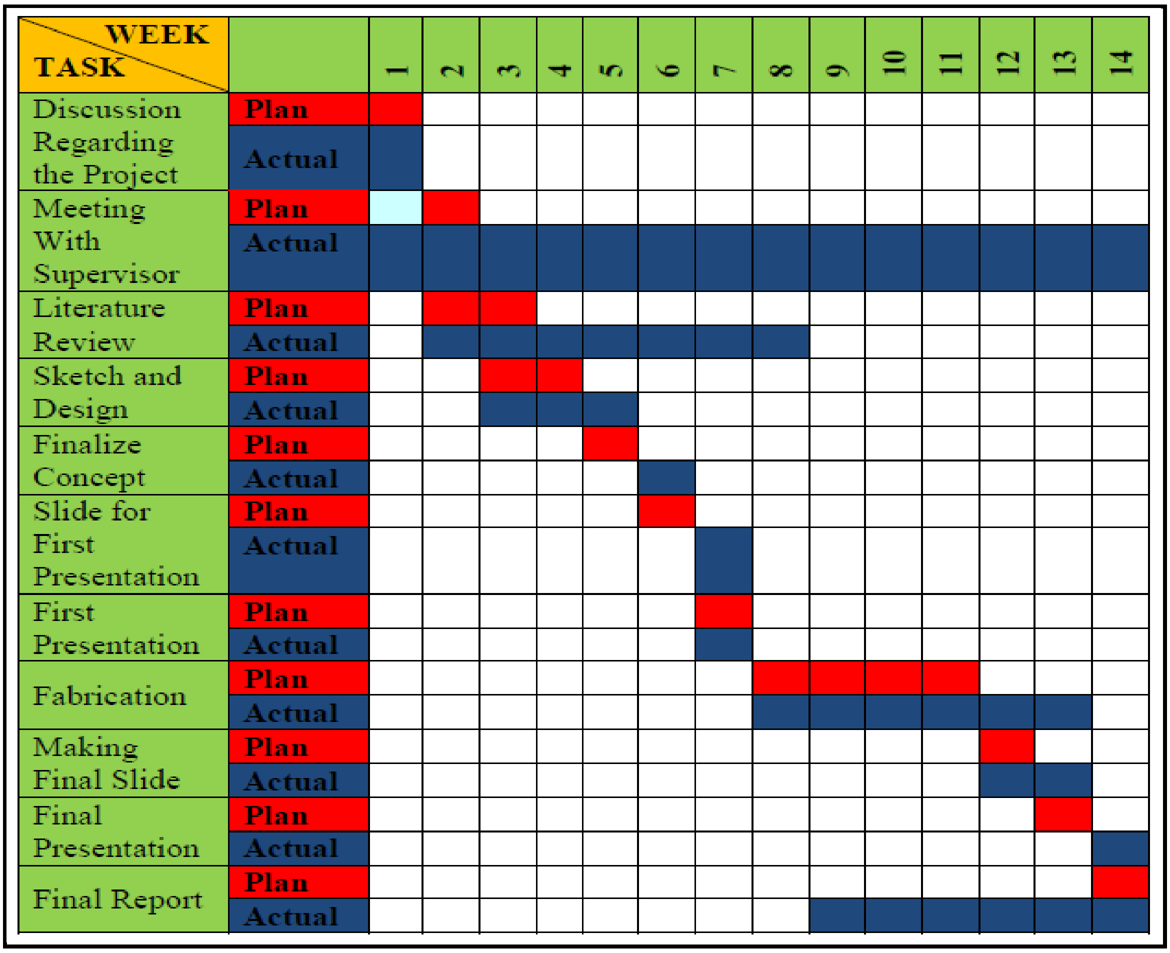

Figure 1.11: Project Gantt Chart

The Process followed for design and fabrication of Steering system involves following steps.

1. Analysis of Previous Year's Vehicle

2. Defining the Objective for New vehicle.

3. Market Survey for the Components used.

4. Steering Geometry Iterations.

5. Design Validation.

6. Steering system parts fabrication.

7. Steering system Assembly.

The solar electric car is a reflection of how modern automotive engineering has progressed over the years. The modern car technology has progressed mostly through the solar electric car industry with dire need to create the fastest and safest car available. Different components and systems have been invented through the need to make work easier and more accurate.

Designing and selection of the most suitable steering system was done through research on the most common ones used in the market with their pros and consnoted. The research was greatly influenced by a set of criterion to lead us to the perfect selection listed below: -

▪Cost.
▪Availability.
▪Complexity.

The main objective is to reduce the turning radius of the vehicle.

The main sources of research were from automotive experts (Mr. Jack who specialises in car hardware components), automotive books, the internet, reports compiled by students that took part in the competitions and articles specialising on the steering system. The various steering systems were carefully considered and the selected system was narrowed down to one that matched our criterion.

The design process was laid out where the initial design was facilitated by determining the dimensions of the race car. The dimensions were carefully chosen by the previous solar electric car student race car project done by the previous year’s project. The steering system Ackermann condition which was suggested by Rudolph Ackermann is still in use today for most cars since it is accurate and accounts for difference in tire angles to prevent slip when turning. Various dimensions of the moving components like the connecting rack and tie rod were found from the Ackermann geometry which made it easier to calculate the sizes and movement of the parts with the angles to be made.

Mechanical movements and dimensions were not enough in the design process since mechanical properties of the materials chosen had to be calculate to prevent catastrophic failure of the components. First, the force transmitted through from the tires to the steering arm through the tie rod to the connecting rack then the rack and pinion gear to the steering rod and finally the steering wheel where the driver uses to turn the tire had to be calculated. The components had to be designed to with stand the force without possible failure with a safety factor of 2 or more. The material selection process was carried out according to the ISO standards.

The rack and pinion selection was based on the F1 standards where the ideal ratio of number of turns has to be as low as 1:12 where normal cars have a steering ratio of 1:20 from lock to lock. The idea is based on the crucial factor of time where more turns translates to higher time consumption and lack of proper control of the vehicle on a turn. Hence the pinion gear had to be bigger to reduce the number of turns made by the driver, which consequently increased the effort needed to turn.

Solar electric car race cars are engineered to move at very high speeds up to 360 km/h but unfortunately the race tracks are not straight and hence the car needs to slow down at corners which brings the need to design better cars to move at higher and higher speeds around corners without toppling over or spinning around due to over steer. Reducing the turning radius enables the car to move at higher speeds around the corner and hence design changes have to be made.

Several design analyses were put to test through varying the turning radius and change in centre of gravity and varying the inner tire angle. The tests and calculations suggested the most suitable weight ratio and tire angles needed to create the best design for maximum effectiveness of turning speeds with the right amount of over steer without causing the car to spin or topple over. A graphical analysis shows the rate at which each degree of variation affects the movement.

A visualisation of the proposed design was shown clearly on a CATIA drawing where the components, exact sizes and movement of the steering system can be simulated. The component that undergoes stresses and deflections were put to test using a stress and deflection of finite element analysis simulation program called ANSYS. The components were able to withstand the acting forces and therefore passed the test.

CHAPTER-2

LITERATURE REVIEW

2.LITERATURE REVIEW

Rudolph Ackermann invented the steering mechanism allowing the vehicle to turn along the flow of the path in early 1800's, called as Ackermann steering. The parallelogram steering mechanism was developed in late 1800's. The major studies performed on the steering mechanisms and steering geometry optimizations are:

S.No.	AUTHOR	WORK	YEAR
1.	Mohammad Kristamto	"Measuring geometric and kinematic properties to design steering axis to angle turn of the electric golf car.", International Conference on Sustainable Energy Engineering and Application.	2015
2.	R.S. Khurmi, J.K. Gupta	"Theory of Machines", S Chand& Company Pvt. Ltd., Vol 1, 14th Edition,	2014
3.	S.K. Gupta	"A Textbook of Automobile Engineering", S. Chand & Company Pvt. Ltd., Vol 1, 1st Edition,	2014
4.	Saket Bhishikar, Vatsal Gudhka, Neel Dalal, Paarth Mehta, Sunil Bhil, A.C. Mehta	"Design and Simulation of 4 Wheel Steering System", International Journal of Engineering and Innovative Technology (IJEIT), Volume 3, Issue 12,	June 2014
5.	Dr.Kirpal Singh,	"Automobile Engineering", Volume 1,	2013
6.	Prabhudatta Das,	Design and fabrication of a go-kart vehicle with improved steering and dynamics, a project report	2012

Table.1. Literature Review

1. Mohammad Kristamto - “Measuring geometric and kinematic properties to design steering axis to angle turn of the electric golf car.”, International Conference on Sustainable Energy Engineering and Application. 2015

2. R.S. Khurmi, J.K. Gupta - “Theory of Machines”, S Chand& Company Pvt. Ltd., Vol 1, 14th Edition, 2014

3. S.K. Gupta - “A Textbook of Automobile Engineering”, S. Chand & Company Pvt. Ltd., Vol 1, 1st Edition, 2014

4. Saket Bhishikar, Vatsal Gudhka, Neel Dalal, Paarth Mehta, Sunil Bhil, A.C. Mehta - “Design and Simulation of4 Wheel Steering System”, International Journal of Engineering and Innovative Technology (IJEIT), Volume3, Issue 12,june 2014

5. Dr.Kirpal Singh, “Automobile Engineering”, Volume 1, 2013

6. Prabhudatta Das, Design and fabrication of a go-kart vehicle with improved steering and dynamics, a project report, 2012

Some other literature reviews are:

- Salaani-developed a real-time torque feedback model of steering system.
- Badawy- electric power steering system to study torque performance, disturbance rejection, noise rejection, road feel and stability.
- Simionesce- kinematic study of a rack and pinion steering.
- Ansarey- optimized the steering geometry to minimize steering errors.
- Adams and Sugitani- studied the driver steering feel.
- Segel- Proposed Quasi linear model for vibration analysis of the steering.
- Mabrouka- Investigated the effects of tire lateral flexibility on the dynamic behaviour of the steering mechanism.
- Gillespie - Developed the geometry and forces & displacements relationship based modelling equations of the steering mechanism.
- Park and Nikravesh- Analyzed the effects of steering compliance on the directional stability of the vehicle.
- Abe- Studied vehicle handling performance by application of variable gear ratio steering system.

Based on the Literature survey currently there is no steering which has incorporated planetary gear sets. However planetary gear sets are used in ship steering mechanisms and vehicles automatic transmission gear boxes.

General steering system in modern vehicle either commercial or owned of a Gear combination. Where the pinion is connected to the steering wheel through steering column and while rotation the steering the pinion is rotated which is in mesh with the rack which converts the rotational motion into linear motions which moves the wheels with various geometry and positioning of the steering unit. In India the cars are mostly found to be front wheel drive and with the arrangement with drive shafts it made the turning of the wheels limited.

Rack-and-pinion steering is quickly becoming the most common type of steering on cars, small trucks and SUVs. It is actually a simple mechanism. A rack and pinion gear set is enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a tie rod, connects to each end of the rack.

A complete survey of the existing steering system of a four-wheeler was made. Currently there is no steering which has incorporated planetary gear sets. However planetary gear sets are used in ship steering mechanisms and vehicles automatic transmission gear boxes. Research papers related to the design of different types of planetary gear set (circular, noncircular), analytical expression for power transmission, ship steering system, were studied.

1. Dr.S.R. Shankapal (2013) developed a four wheel steering system for a car. Production cars are designed to understand and rarely do they over steer. If a car could automatically compensate for a over steer problem the driver would enjoy nearly neutral steering under varying operations conditions. In situation like low speed cornering, vehicle parking and driving in city conditions with heavy traffic tight spaces. Driving would be very difficult due to vehicles larger wheel base and track width. Hence there is a requirement of a mechanism which results in less turning radius and it can be achieved by implementing four wheel steering mechanism instead of regular two wheel base.

2. S.H.Yadav (2013) made an investigation of failure of planetary gear train due to pitting, planetary gear train is a gear system consisting of one or more planet gears, revolving about a sun gear. And it is widely used in industries. An epicyclical gearing system is particularly well suited for achieving a high reduction ratio in a relative small, power dense package. It is widely recognized that the load sharing is not equal among the planetary gear meshes. Similarly the stress distribution at each mesh point contains variability. Pitting is a surface fatigue failure of the gear tooth. It occurs due to misalignment; wrong viscosity selection of lubricant used, and contact stress exceeding the surface fatigue strength of the material.

3. R. Masilamani (2015) made an experimental analysis of reducing steering ratio to reduce turning ratio, the concept has been developed to reduce the driver's effort during parking or

maneuvering sharp curves. Using the additional planetary gear set with the existing steering gear box, steering ratio can be changed and hence the input speed to the steering wheel can be altered when to the steering gear box. On installing the planetary gear set and the modified rack and pinion steering gear box, the number of rotations made by the steering wheel for the given angle of road wheel rotation is altered.

4. Dr.Dinesh.N.Kamble has developed a concept based on the analysis of the transmission mechanism of angle superposition with active front steering system. A controller of variable steering ratio for AFS system is designed and virtual road tests are made in car. The results of simulation tests validate the controller performance and the advantage of the variable steering ratio function, also show that the driving comfort is International Journal of Pure and Applied Mathematics Special Issue 252 improved at low speed especially due to the active front steering system alters the steering ratio according to the driving situation.

5. P.A.Simionescu, llieTalpasanu (2006) synthesized the Ackermann linkage and steering control mechanism. And they concluded that it was required to maintain the steering error within acceptable values, so that the symmetric steering control is ensured for left and right of the vehicle. They used Nelder Mead simplex algorithm and AUTOCAD for their research.

6. Jose M.del Castillo (2001) in their research obtained the analytical expression for the efficiency of any planetary gear train using Cramer's rule. They find the gear tooth ratio employing a speed and torque equations and gearing power and speed ratio.

7. D.Mundo (2006) Designed a planetary gear trains to generate a variable angular velocity ratio using non- circular gears by using CAD software, PTC-pro engineer. He reduced the typical torque fluctuations of a low speed way of pedaling in order to maximize the output.

8. Daniele Vecchia to (2005) did a tooth contact analysis of an isostatic gear train for various cases. TCA proved to be a self-regulated system due to the existence of floating gears. Such a system is not sensitive to most errors of alignment.

9. Rince Wins, DhaneshChatta& Anish Nair [1] had studied the steering wheel is the important part of the four wheeler thus cause of fatal injury for drivers in frontal collision. When frontal collision occurs, due to the kinetic energy of driver or occupant body, it moves forward against steering wheel and wind shield. Actually in a frontal collision forces will be first transmitted through driver's feet which act as fulcrum so the body will rotate about it. Driver head & chesthit the steering or windshield which may cause severe injury or death. For the taller driver steering works as fulcrum. Considering the injury potential of steering wheel we are presenting a new idea Pneumatic Collapsible Steering Column.

When the steering column was first invented, it consisted of a single long steel rod which connecting the steering wheel to the steering gear box. While this single-piece construction was efficient, and effective in controlling the vehicle, it soon became apparent that its design was unsafe in frontal collisions. Under the single-piece system, when such an impact occurred, the steering column would often impale the driver as it was rammed toward the rear of the vehicle. A collapsible steering column is a mechanism that is used to transfer power from the steering wheel into the steering gear box, which transfers power to turn the wheels of a vehicle. Existing collapsible steering columns still consist of a long shaft that connects the steering wheel to the steering gear box. However, the collapsible design is composed of an inner and an outer sleeve, engaged tightly together with a number of steel bearings in between the sleeves. These steel bearings are pressed into the metal sleeves, and are held in place with a strong safety resin, which is designed to harden and then shatter when a specific level of pressure is applied. In the event of a frontal impact, the steel bearings between the sleeves break free, allowing the inner sleeve to be moved further into the outer sleeve in telescopic fashion before enough pressure is achieved to ram the whole steering column into the driver. In this manner, the energy received through a frontal impact is completely absorbed by the steering column’s collapsible parts.

10. S.Nithyananth, A.Jagatheesh, K.Madan, B.Nirmalkumar [3] presented most conventional and general steering arrangement to turn the front wheels using a hand operated steering wheel which is positioned in front of the Driver. The steering column, which contain an universal joint which is part of the collapsible steering column which is designed to allow it to deviate from a straight line according to the Roadmap. In convertible four wheel steering with three mode operation, three steering modes can be changed as needed which assists in parking at heavy traffic conditions, when negotiating areas where short turning radius is needed and in off road Driving. The project carried out by us made an impressing task in the field of automobile industries. It is very usefully for driver while driving the vehicle. This project has also reduced the cost involved in the concern. Project has been designed to perform the entire requirement task which has also been provided.

11. Malge Sangeeta Ganesh, G. P. Patil , N. A. Kharche [4] presented by steering shaft is a media between steering wheel and steering box in overall steering system. In this Paper Various Structural analyses such as Static-Structural, Modal Analysis of a steering rod are done. Static-structural analysis is capable to find out deformation in body in which Von-mises stress are calculated and this state that up to what extent the deformation in the rod occurs. while modal analysis is important in vibration point of view. i.e. Vibrations in body can be calculated up to what frequency the steering rod can sustain the load or Harmonic frequency of the body from above Optimization of steering rod can be done. In this paper structural analysis is done to find the maximum deformation of the steering rod and stresses in the steering rod and it is noted that the deformation is negligible and the stresses by von-mises stress are below the yield point stress so the steering rod is safe. Maximum deformation occurs at the corner points of the circular hole at both the ends of the rod and the stresses are also maximum at the corner points. Modal analysis is done to calculate the Harmonic Frequency of the rod. The frequencies of the rod are calculated in five sets. In all five stages behaviour of the rod is different i.e. it varies from 1Hz to 39.66Hz. From this it is clear that Harmonic frequency is 39.66Hz. Further this frequency can be used to do the Harmonic analysis of the steering rod and for Optimization.

12. Tyan, T., Vinton, J., Beckhold, E., Zhang, X. etal. [5] presents paper on the final phase of a study to develop the modelling methodology for an advanced steering assembly with a safety-enhanced steering wheel and an adaptive energy absorbing steering column. For passenger cars built before the 1960s, the steering column was designed to control vehicle direction with a simple rigid rod. In severe frontal crashes, this type of design would often be displaced rearward toward the driver due to front-end crush of the vehicle. Consequently, collapsible, detachable, and other energy absorbing steering columns emerged to address this type of kinematics. These safety-enhanced steering columns allow frontal impact energy to beabsorbedbycollapsingor breaking the steering columns, thus reducing the potential for rear column movement in severe crashes. Recently, more advanced steering column designs have been developed that can adapt to different crash conditions including crash severity, occupant mass/size, seat position, and seatbelt usage. These advanced steering columns incorporate adaptive features, mechanically or pyrotechnically activated, to add flexibility in absorbing impact energy of different levels.

In the final phase of the study, the focus is the modelling of an advanced steering wheel and column assembly that can be used in frontal and side impact simulations. In the first phase of the study, ten component and subsystem tests were conducted to develop the modelling methodology of an adaptive energy absorbing steering column assembly. Three steering wheel assembly tests and eight steering wheel and column assembly tests, with the steering column being mounted in normal and offset angles, were developed and conducted in the final phase of the study. In addition, various dynamic impact speeds, including quasi-static, were considered so that speed sensitivity of the steering wheel and column assembly could be obtained. The final modelling methodology of the steering wheel and steering column assembly is developed based on reasonable correlation achieved with twenty-one tests. The developed modelling methodology can be applied to other advanced steering wheel and column assemblies and will enhance evaluation of occupant responses in full vehicle or subsystem simulations. It can also be used in finite element analysis programs and/or coupling of finite element and occupant analysis programs. The final goal of this study is to utilize the developed modelling methodology in vehicle development to occupant safety systems, optimize prototype testing and enable faster development cycle time.

13. Bengt Pipkorn Autoliv,Yngve Håland Autoliv.[6] presented by the structures of modern passenger vehicles are designed to maintain integrity up to an impact velocity of about 64 km/h (40 mph). The occupant protection system is likewise designed to efficiently protect the occupant up to an impact velocity of 64 km/h. However, there are highways with a 90 km/h (56 mph) speed limit without separation of the lanes and many car occupants still die in severe frontal crashes. To investigate the level of occupant protection at very high impact velocity a full frontal full vehicle rigid wall crash test with a mid-size passenger vehicle was carried out. The impact velocity was 80 km/h (50 mph). A 50%-ile Hybrid III crash test dummy was positioned on the driver side. The dummy results show that the possibility of survival of an occupant in that particular vehicle in such a crash was minimal. With the goal to develop a protection system that in an 80 km/h (50 mph) crash test would result in dummy

reading below the FMVSS 208 injury criteria levels a mathematical sled model was developed and a mechanical sled mock-up was setup.

14. Zeeshan Qaiser, Omer Masood Qureshi Khalil Aslam, Awan Hassan Ahmed. [7] Presented by Collapsible energy absorbers are encouraged in the field of automotive in the past decade due to their good energy absorption characteristics. Impact energy absorbers dissipates maximum amount of energy during an axial impact. Impact of steering wheel with ribs of driver during an accident is an area of prime concern. A patterned steering column is proposed in the present work which turns into inverting tube and absorb good amount of energy during an accident. The inversion process is induced in steering column by embedding sinusoidal patterns over it. This process is numerically investigated by using commercially available non-linear solver LS-DYNA(TM). Different steering column arrangements are studied and force-displacement results are analyzed in this work. A study is performed to investigate and compare energy absorption parameters of conventional and pr oposed design of steering column.The results show that the energy absorption with proposed sinusoidally patterned steering column is better than conventional steering column.

15. Ratko Menjak, Karen A. Boswell, SainanFeng, James P. Kelly, Brian J. Magnus, Wayne M. Steverson. [8] described that a collapsible steering column assembly preferably has a collapsible steering shaft that extends rotatably along a centreline and a collapsible column that houses and co-extends with the shaft. The column preferably has inner and outer tubes that retract telescopically when the column collapses. An energy absorbing (E/A) device has a member that preferably is a strap engaged between the inner and outer tubes and controls the collapse of the column generally via a high load stage and a low load stage of operation. The member is preferably elongated axially having a distal end that is looped over and spaced radially outward from the remainder of the member. The distal end is disengagably attached to the outer tube via a pin received in a hole in the distal end and a fuse engaged operably to the pin and attached to the outer tube.

The E/A device preferably exerts a variable resistance along collapse stroke of the column. In one embodiment of the present invention, the E/A device variably accommodates: low load stage for use with, e.g., a smaller driver, lower speed of vehicle, and or the driver being belted; the high load stage is preferably for use with, e.g., a heavier driver, high speed of vehicle, and or the driver being unbelted driver. Such an embodiment may include one plastically-deformable strap with two stages. Another embodiment of the present invention provides a three stage E/A device accommodating minimum, middle and maximum loads or E/A capabilities. In either the two or three-stage embodiments, which stage to be appropriately applied will depend on selective activation of one or more of the fuses, that are preferably of a pyrotechnic type, in response to conditions determined from sensors measuring: vehicle speed, weight of driver, seat position and belt function.

The present invention provides the ability to match E/A to load curves of different shapes duringcollapsofthecolumn.The present invention achieves this result, in either of the two abo vementioned embodiments with a single, one piece strap thatdeforms without friction to ensure a stable E/A process with maximum simplicity and low cost.

16. Tyan, T., Vinton, J., Beckhold, E., Zhang, X. [9] described that The objective of this paper focused on the modelling of adaptive energy absorbing steering column which is the first phase of a study to develop a modelling methodology for an advanced steering wheel and column assembly. Early steering column designs often consisted of a simple long steel rod connecting the steering wheel to the steering gear box. In frontal collisions, a single-piece design steering column would often be displaced toward the driver as a result of front-end crush. Over time, engineers recognized the need to reduce the chance that a steering column would be displaced toward the driver in a frontal crash. As a result, collapsible, detachable, and other energy absorbing steering columns emerged as safer steering column designs. The safety enhanced construction of the steering columns, whether collapsible, detachable, or other types, absorb rather than transfer frontal impact energy. Recently, more advanced steering column designs with adaptive features, mechanically or pyrotechnically activated, have been introduced for different crash conditions, including different crash severity, occupant mass/size, seat position and seatbelt usage. These steering columns are able to absorb different impact load conditions ranging from high impact load for larger and/or unbelted crash dummies in higher severity crash tests to low impact load for smaller and/or belted drivers in lower severity crash tests. With the steering column designs becoming more complex, the modelling of a steering column with advanced safety features also becomes more challenging.

To optimize prototype testing and enable faster development cycle time,, an attempt was made to model the steering assembly with advanced safety features. The modelling study was divided into two phases, with the first phase focusing on the modelling of an adaptive energy absorbing steering column as discussed in this paper. The modelling of an advanced steering assembly, with a safety-enhanced steering wheel and an adaptive energy absorbing steering column for frontal and side impact simulations, was developed in the second phase of the study and will be presented separately. To provide information for modelling methodology development, component and sub-system tests were developed and conducted to understand the mechanical behaviours of different energy absorbing features as well as the performance of the adaptive mechanism in the steering column design. Different dynamic impact speeds, including quasi-static tests, were also included in DOE test matrices so that collapse speed sensitivity of the steering column components could be obtained. Finite element modelling methodology was developed and presented based on its correlations with the steering column component and sub-system tests.

17. M. Balaji, MalarMohan. [7] studied that energy absorption load of steering column shaft assembly and reduce failure due to noise. It also reduces the dependency of process parameters which is considered as important factor in existing injection melding process. Energy Absorbing Steering Column is a kind of Steering Column which minimizes the injury to the driver during a car meets accident by collapse particular part of system. The design of

the steering column has remained unchanged since its inception; the column still consists of a long shaft connecting the steering wheel to the vehicle's gearbox.

Column shaft assembly is made by joining shaft and tube through injection moulding process which has high variation and dependency on process parameters. Energy absorption load will be ensured by periodic inspection of parts an d setting parameters. To overcome theexisting problem, we proposed crimping method to join shaft and tube assembly and ensure energy absorption load during the process and improve the performance of the steering column assembly.

From the literature review, various kinds of steering systems and designs inexistence that have been used have been looked at. Therefore, a system had to be chosen that will be suitable for the student race car and that will be able to achieve the objective.

CHAPTER-3
STEERING SYSTEM

3. STEERING SYSTEM

To achieve all these, guidelines had to be set for the design. These guidelines were set by selecting adequate and essential design parameters. Some other guidelines that were set were how to achieve the desired objective from the problem statement.

The turning radius was reduced through:
• Over-steer: the front to back weight distribution was selected as 40:60.
• Selecting a suitable material that is light and strong enough for the design.
• Ensuring that the steering ratio is a value less than 8.

3.1 Design Parameters

The design concept is based primarily on the design parameters set up by the previous race car project for the steering wheel.

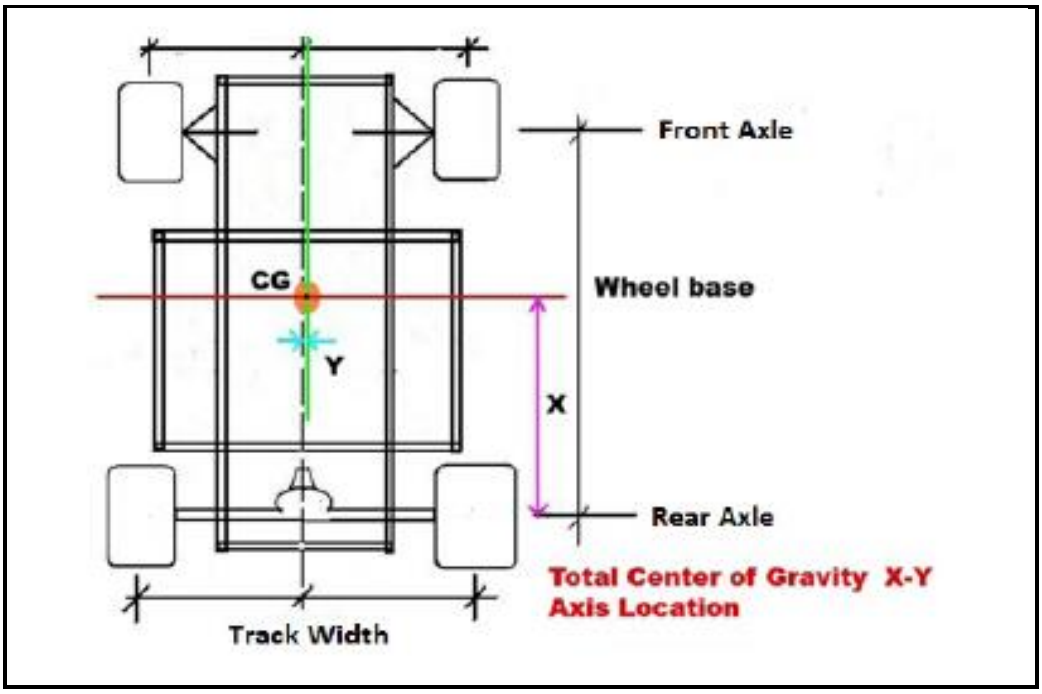

Figure 3.1 Positioning of the track width, wheel base and centre of gravity (http://www.racecartuning.com/alignment.html)

The above parameters are some of the essential vehicle parameters that will be used to find the turning radius of the vehicle. As stated above, the weight distribution of the student race car is 30:70. Thus the weight at the front is 90Kgsand the weight at the back is 210Kgs. This weight distribution is measured from the centre of gravity to the absolute ends of the race car. The indicated length is the length from the nose to the rear wing.

3.2 Working Principle of a Two Wheel Steering System

This project involved design of a two wheel steering system which will reduce the turning radius. For the Formula 1 student race has its steering system positioned centrally, unlike in normal road cars where the steering system is either to the right or left. This makes the manoeuvring ability easier. From the many available forms of the steering system, the rack and pinion steering system was selected due to its ease in usage and maintenance. It has fewer parts, it is lighter, it gives better and quicker feedback and it is easy to repair.

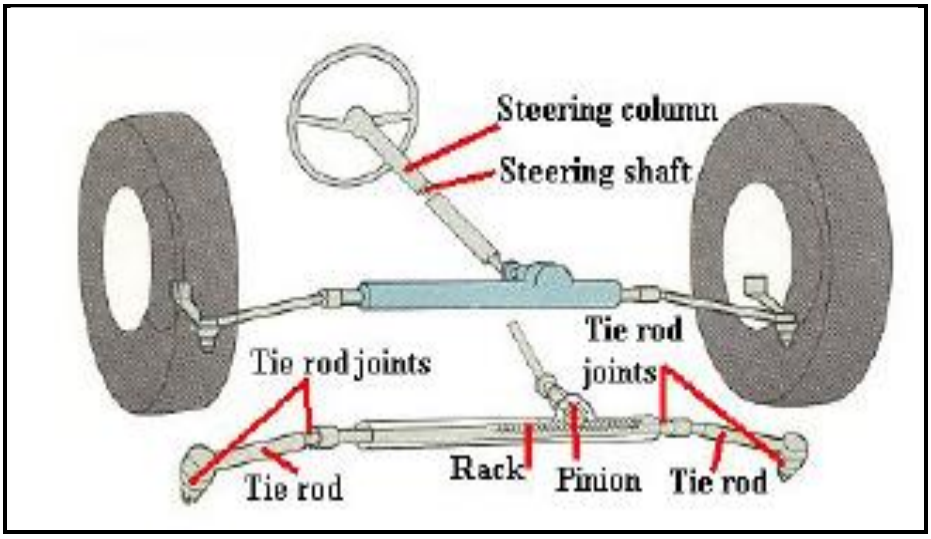

Figure 3.2 Parts of a steering system
(http://m5carblog.blogspot.co.ke/2013/02/steering.html)

A rack-and-pinion gear set is enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a tie rod, connects to each end of the rack. The pinion gear is attached to the steering shaft. When you turn the steering wheel, the gear spins, moving the rack. The tie rod at each end of the rack connects to the steering arm on the spindle. Both the pinion and the rack teeth are helical gears. Helical gearing gives smoother and quieter operation for the driver.

Mechanical advantage is gained by the reduction ratio. The value of this ratio depends on the size of the pinion. A small pinion gives light steering, but it requires many turns of the steering wheel to travel from lock, to lock. A large pinion means the number of turns of the steering column is reduced, but the steering is heavier to turn.

Once the tyres start turning, the Ackermann effect takes place to avoid slipping of the front tyres. Thus the inner front tyre turns at a larger angle than the outer front tyre so as to avoid slipping. As the race car moves round a corner at high speed, the rear tires tend to slip due to most of the weight of the car being at the back; 70% of the weight is at the back. The slipping of the car in this manner causes over-steer and this phenomenon reduces the turning radius of the car. The driver should on the other hand maintain the car in control to avoid spinning out of the car due to too much over-steer. This is why the steering ratio should be low enough to make the steering system sensitive.

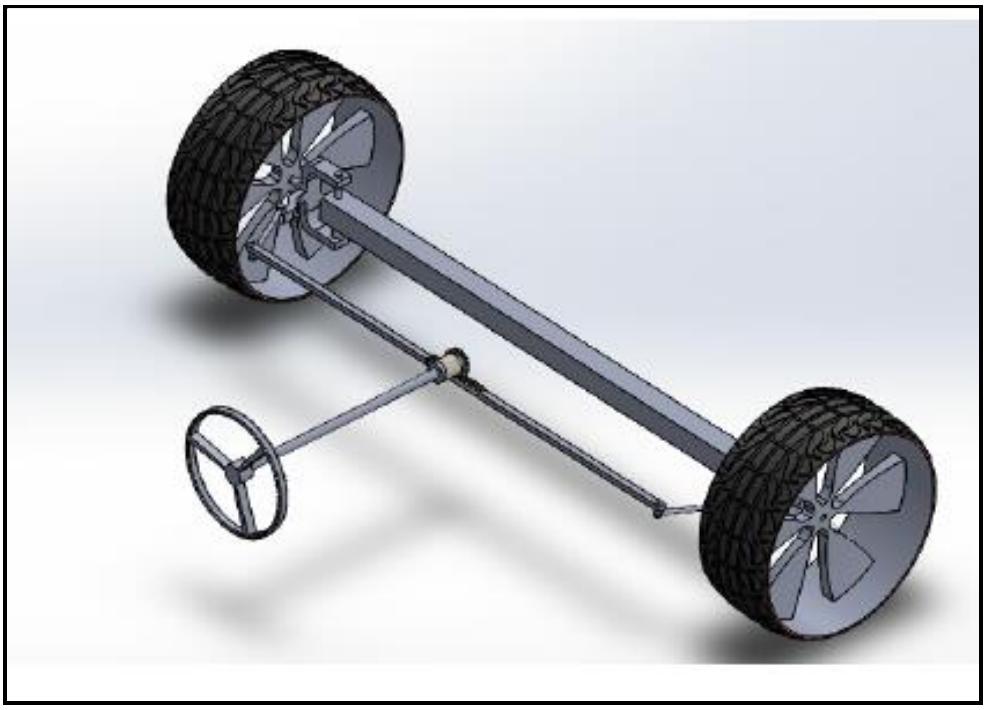

Figure 3.3 Isometric view of the simulated steering system

CHAPTER-4
SELECTION OF MATERIALS

4. MATERIALS SELECTION

A material has attributes: its density, strength, cost, resistance to corrosion, and so forth. A design demands a certain profile of these: a low density, a high strength, a modest cost and resistance to sea water, perhaps. It is important to start with the full menu of materials in mind; failure to do so may mean a missed opportunity. If an innovative choice is to be made, it must be identified early in the design process.

There are four main steps, which are translation, screening, ranking and supporting information. The first step in tackling it is that of translation, examining the design requirements to identify the constraints that they impose on material choice. The immensely wide choice is narrowed, first, by screening-out the materials that cannot meet the constraints. Further narrowing is achieved by ranking the candidates by their ability to maximize performance. Criteria for screening and ranking are derived from the design requirements for a component by an analysis of function, constraints, objectives, and free variables.

The material selection process begins with the family of materials. From this family material are eliminated slowly to remain with the final best material to be used for the design process.

The family of materials includes:

- Ceramics
- Glasses
- Metals
- Polymers
- Elastomers
- Hybrids
- Wood

1. Translation

Function and constraints, objective and free variables define the boundary conditions for selecting a material. Translation involves setting these boundaries that the design is subject to. For our steering system design, these boundaries include:

- To be able to support load
- To contain pressure exerted to the wheels
- To be as light and strong as possible
- To avoid any buckling in the design
- Cheap enough
- To survive under all conditions

2. Screening

Unbiased selection requires that all materials are considered to be candidates until shown to be otherwise. The first of these eliminates candidates that cannot do the job at all because one or more of their attributes lies outside the limits set by the constraints. The materials eliminated were:

• Ceramics- this family was eliminated since its dimensional tolerance is difficult to control during processing, it is weak in tension, it has poor shock resistance, and it can crack when hit with heavy items.

• Glasses- it was eliminated because it is an expensive material, it breaks easily and when broken, the pieces may cut you.

• Elastomer-these were eliminated since they are relatively expensive

3. Ranking

This is the process of arranging materials form the best to the worst based on a certain criteria. In this case it was done according to the stiffness of the remaining families (from the graphs).

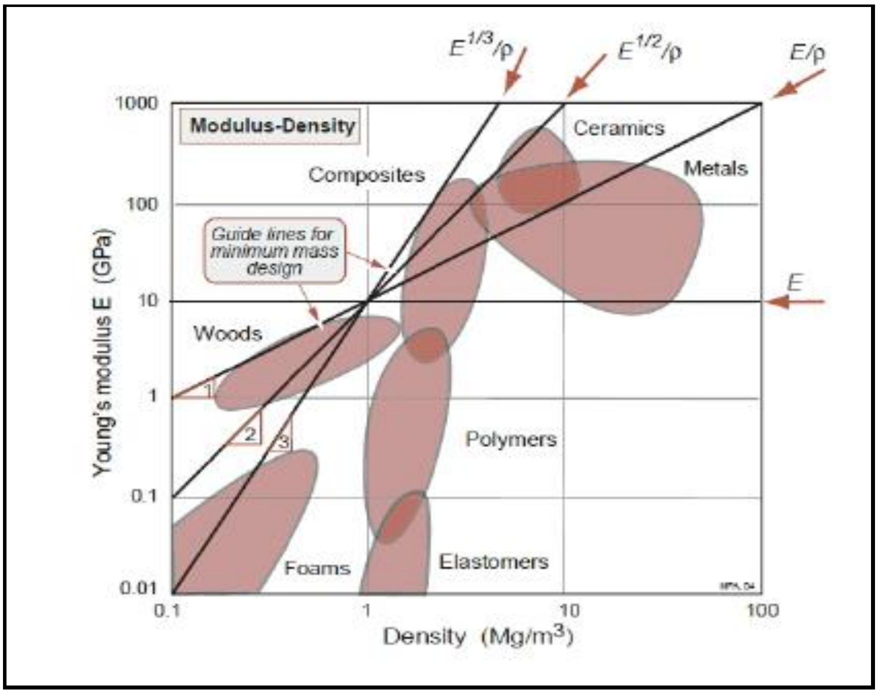

Figure 4.1: Young's Modulus for various materials [7]

The ranking from highest to lowest was:

• Metals
• Hybrids
• Wood
• Polymers

4. Support information

For making the steering system we required a material that is malleable and has high strength properties. From research it was found that metal was the most appropriate material. Most metals are strong enough to withstand an appropriate amount of load and it is relatively easy to cut through.

5. Local conditions

Metal is readily available in the Kenyan market and is fairly cheap. Hence metal is the material best suited for making the drawers.

4.1 Metal Selection

There are various kinds of metals and we have to select one. So we re-do the material selection steps.

a) Translation

We had to choose one form of metal that is suitable for our design. For our design, we had to have a metal that is:
a. Ductile
b. Malleable
c. Corrosion resistant
d. Tough
e. Cheap.

TOUGHNESS	BRITTLENESS	DUCTILITY	MALLEABILITY	CORROSION RESISTENCE
Copper	White Cast Iron	Gold	Gold	Gold
Nickel	Grey Cast Iron	Silver	Silver	Platinum
Iron	Hardened Steel	Platinum	Aluminium	Silver
Magnesium	Bismuth	Iron	Copper	Mercury
Zinc	Manganese	Nickel	Tin	Copper
Aluminium	Bronzes	Copper	Lead	Lead
Lead	Aluminium	Aluminium	Zinc	Tin
Tin	Brass	Tungsten	Iron	Nickel
Cobalt	Structural Steel	Zinc		Iron

Bismuth	Zinc Monel Tin Copper Iron	Tin Lead		Zinc Magnesium Aluminium
*Metals/Alloys are ranked in descending order of having the property named in the column heading.				

Table.4 Properties of different Metals

b) Screening

Using this table, we were able to narrow down to a few metals. These included gold, silver, aluminium, copper, tin, lead, zinc and iron. From these, the following were eliminated using our objectives:

i. Gold and silver were immediately disqualified because from our objectives, we needed a metal that is in-expensive.

ii. Lead was also eliminated since it is quite a heavy metal. It weighs about320Kgs per cubic foot.

iii. Tin was eliminated since at very low temperatures; it has a tendency to decompose.

c) Ranking

We thus remained with aluminium, copper, zinc and iron. From these we ranked the materials from the best to the worst. We did this using the table above where the materials were arranged in descending order. Thus we arranged them in their various categories as follows in descending order:

Toughness	**Ductility**	**Malleability**	**Corrosion Resistance**	**Cheapness**
1. Copper 2. Iron 3. Zinc 4. Aluminium	1. Iron 2. Copper 3. Aluminium 4. zinc	1. Aluminium 2. Copper 3. Zinc 4. Iron	1. Copper 2. Iron 3. Zinc 4. Aluminium	1. Iron 2. Aluminium 3. Zinc 4. Copper

Table.5 Ranking of Metals

From the ranking, we are able to see that iron is the best suited material for our design.

d) Support Information

Iron in itself is a very brittle material under tension but very strong in compression. Thus modifications have to be done to it so as to strengthen it. To achieve this, we have to increase the carbon content in the iron. Increasing the carbon content results in an increase in yield stress and ultimate tensile stress, while the elongation remains essentially constant. This thus turns the iron into steel.

e) Local Conditions

There are various forms of steel in the market, but we have to pick one that is readily available and cheap enough to build the student race car steering system. We found out that mild steel was easily available to us.

Mild steel has the following mechanical properties:

Material Property	Magnitude
Modulus of Elasticity	200GPa
Tensile strength	455MPa
Yield strength(tension)	250MPa
Ductility, percent elongation in 50mm	23
Poisson’s ratio	0.29

Table.6 Properties of Mild Steel

Thus mild steel will the material used to design most of the steering system components.

The materials used in the steering system target precise operation and light weight components. Although precision and weight are the top priorities, cost, manufacturability, and reliability were also considered. Precision in the steering system is derived from high manufacturing tolerances and minimal deflection. Deflection in any component leads to steer compliance, resulting in an unresponsive steering system.

The pinion and idler gears were purchased, which limited material options but reduced manufacturing time. Although these gears are steel, they have a smaller face width than a comparable aluminium gear. The rack gear is Turned, Ground and Polished (TGP) 1042 carbon steel rod. The TGP material is more precise than standard round stock and the TGP finish removes surface tension inherent from standard extruding. This reduced the risk of the rack gear bending when the gear teeth were cut. The higher strength of the steel also allowed for extra material to be removed without introducing steer compliance. In addition to the precise material, the steel on steel gear mesh is advantageous for reliability. A softer material in the gear mesh would increase the possibility of galling, and compromise precision over time.

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STEEL TYPE	VEW	HEAT TREATMENT				CORRESPONDING SPECIFICATION		
		Hardening Temperature	Quenching Medium	Tempering Temperature	Brinell Rock well hardness	JAPAN JIS	AISI	POLDI THREAD
EN SERIES STEEL	EN-1A	-	-	-	-	-	-	-
	EN-8	750-900	OIL	150-200				
	EN-9	850-900	OIL	200-250	55-60			
	EN-19 (V 320)	900-950	OIL	200-225	45-55	SCM 4	4140	
	EN-24 (V 130)	830-860	OIL	540-680	45-55	SNCM 8	4340	
	EN-31 R-100	820-860	OIL	180-225	59-65			
	EN-36C E-200	780-860	OIL	170-210	61-63	SNC 22	3415	
	EN-42	600-700	DIRECT HARDENING		40-45			
	EN-44	650-750	OIL	150	45-50			
	EN-45	830-860	OIL	470-520	50-55		9255	
	EN-351	850-860	OIL	175-200	62-64			
	EN-353	840-870	OIL	150-200	62-64			

Table.7 Comparison of Materials & Properties

4.2 CHEMICAL COMPOSITION OF MATERIALS

EN-19		EN-24		7075-Al ALLOY	
Carbon	0.35-0.45	C	0.36-0.44	Al	87.1-91.4
Manganese	0.50-0.80	Mn	0.45-0.70	Mn	0.3
Silicon	0.10-0.35	Si	0.10-0.35	Si	Max. 0.4
Nickel	---	Ni	1.3-1.7	Zn	5.1-6.1
Molybdenum	0.20-0.40	Mo	0.2-0.35	Cu	1.2-2.0
Chromium	0.90-1.50	Cr	1.0-1.4	Cr	0.18-0.28
Sulphur	0.05	S	0.04	Fe	Max 0.5
Phosphorous	0.05	P	0.035	Mg	2.1-2.9

Table.8 Chemical Composition of Materials

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Density of EN19 Alloy steel material: 7.85kg/cm3

Engineering Alloy Steel material EN19 yield strength: 555-755 N/mm²

Tensile strength of EN19 Engineering steel: 775-1075 N/mm²

Engineering steel material EN19 hardness in HRc:

Flame or induction hardening can give a case hardness of 50 HRc or higher.

EN19 equivalent material with AISI 4140, DIN 42CrMo4 EN 1.7225, GB 42CrMo, JIS SCM440C alloy engineering steel

EN19 alloy structure Steel heat treatment

Thermal processing temperature / ℃|Forging: 1050 ~ 850

The heat treatment temperature / ℃ | Annealing: 680 to 720

The heat treatment temperature / ℃ | normalizing: 840 to 880

The heat treatment temperature / ℃ | quenching: 820 ~ 850 830 ~ 860 oil water

The heat treatment temperature / ℃ | Tempering: 540 to 680

Hardness after annealing ≤HBS: 241

Steel Dimensions / mm: ≤16

After quenching and mechanical properties | σb≥ / MPa: 1100 ~ 1300

After quenching and mechanical properties | σs≥ / MPa: 900

Mechanical properties after quenching | δ5≥ / (%): 10

4.3 MECHANICAL PROPERTIES OF MATERIAL

Forging

Pre heat carefully, then raise temperature to 850-1200°C for forging. Do not forge below 850°C. After forging cool slowly in still air.

Annealing

Heat the EN19T slowly to 680-700°C. Cool in air.

Hardening

This steel grade is commonly supplied ready heat treated. If further heat treatment is required annealed EN19 should be heated slowly to 860-890°C and after adequate soaking at this temperature quench in oil. Temper as soon as tools reach room temperature.

Tempering

Heat carefully to a suitable temperature selected by reference to a tempering chart or table. Soak at the temperature for 2 hours per 25mm of ruling section, then allow to cool in air. Tempering between 250-375°C is not advised as tempering within this range will reduce the impact value.

Heat Treatment

Heat treatment temperatures, including rate of heating, cooling and soaking times will vary due to factors such as the shape and size of each steel component. Other considerations during the heat treatment process include the type of furnace, quenching medium and work piece transfer facilities. Please consult your heat treatment provider for full guidance on heat treatment of EN19T alloy steel.

4.4APPLICATION

EN19T was originally introduced for the use in the machine tool and motor industries for gears, pinions, shafts, spindles and the like. Later its applications became much more extended and it is now widely used in areas such as the oil and gas industries. EN19T is suitable for applications such as gears, bolts, studs and a wide variety of applications where a good quality high tensile steel grade is suited.

- A representative composition of AISI4140 steel also known as EN19 (medium carbon low alloy steel) is utilized to produce ferrite martensite dual phases of varied proportions by inter critical annealing treatment followed by heat treatment to different temperatures and rapid quenching. Mechanical test is essential part of any engineering activity. Mechanical test is applied to the materials, components and assemblies. It consists of measurement of fundamental properties or measurement of responses to particular influences such as load5, temperature, etc. Types of mechanical tests carried out in EN19 (AISI4140) material are tensile test, Impact test and Hardness test. Table.8 shows the chemical composition of the material.

CHAPTER-5
BILL OF MATERIALS

5. QUOTATION

QUT Inbox x

BHARAT METALS <bharatmetals2001@yahoo.in> 2:24 PM (10 hours ago)

to me

DEAR SIR,

EN-19 ROUND 40MM 40MTR 65=00 PER KG
EN-19 ROUND 40MM 40 MTR 680=00 PER MTR

TAX:- 18% GST
PAYMENT IMMIDATE

Thanks & regards
Bhavesh Jain

BHARAT METALS.
Plot No.146A, Sector No-7
P.C.N.T.D.A., M.I.D.C. Bhosari,
Pune - 411026
Maharashtra , India.
Mobile:-+91 9763203620
Email: bharatmetals2001@yahoo.in
Web: http://www.bharatmetalspune.in
SPECIALIST IN :-D2-D3-1.2379-OHNS-H-13-DB6-P20-C45

BHARAT METALS
bharatmetals2001@yahoo.in
Show details

D Y PATIL SCHOOL OF ENGINEERING ACADEMY TALEGAON, PUNE

Department of Mechanical Engineering

ESVC Budget 2018

Sr.	Particular		Unit Cost	Quantity	Market Survey	
1	**Frame Fabrication**					
3	**Steering**					
		Rack & Pinion (material)	65 /Kg	20 Kgs	Rajasthan steel, Bhosari, Pune.	1300
		Steering column (As per design)	500	1	Rajasthan steel, Bhosari, Pune.	500
		Steering wheel (As per design)(Aluminium made with cushioning)	2000	1	Rajasthan steel, Bhosari, Pune.	2000
		Bearings (coloum, rack & pinion)	400	2	Bhosari, Pune	800
		U Joints Steering	800	2	Bhosari, Pune	1600
		Quick Release Hub (material + Manufacutirng)	6000	1	Pratik enigneering works	6000
		Tie rods (OD 12 mm, Thickness 3 mm)	450	2	Rajasthan steel, Bhosari, Pune.	900
4	**Brakes**					
		Pedal assembly (As per design)	4500	1	In house	4500

Table 1 Sheet1

CHAPTER-6
STEERING ALIGNMENT GEOMETRY

6. THE ALIGNMENTGEOMETRY

Geometric Parameters

6.1 Ackermann Condition

Ackerman steering geometry is used to change the dynamic toe setting, by increasing front wheel toe out as the car is turned into the corner. Racers are interested because of the potential to influence the handling of the car on corner entry and mid corner. [4]

The typical steering system, in a road or race car, has tie-rod linkages and steering arms that form an approximate parallelogram, which skews to one side as the wheels turn. If the steering arms are parallel, then both wheels are steered to the same angle. If the steering arms are angled, as shown in the figure below, this is known as Ackerman geometry. The inside wheel is steered to a greater angle then the outside wheel, allowing the inside wheel to steer a tighter radius. The steering arm angles as drawn show 100% Ackerman. [4]

When a car goes round a corner, it turns around a point along the line of its rear axle, which means the two front wheels will have to turn through slightly different angles so that they are also guiding the vehicle round this point, and not fighting the turn by scrubbing. [5]

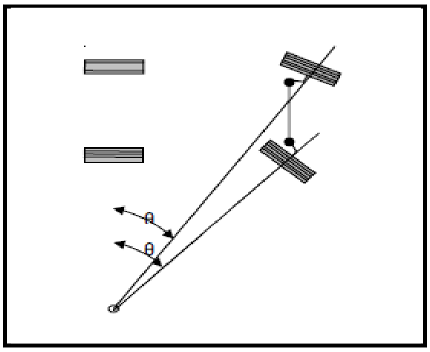


Figure 6.1: Ackermann Principle [7]

Ackerman geometry results when the steering is done behind the front axle and the steering arms point toward the centre of the rear axle as seen on Figure below

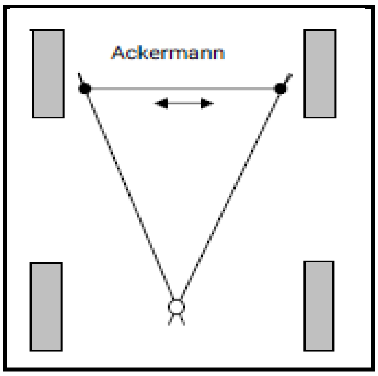


Figure 6.2: Ackermann Construction [6]

For the Ackermann analysis the Ackermann condition is used to determine the relationship between inner and outer wheel in a turn and the radius of turn.
General equation:

$$\frac{1}{Tan\theta o} - \frac{1}{Tan\theta i} = \frac{B}{L}$$

Where:
θ_o= turn angle of the wheel on the outside of the turn
θ_i= turn angle of the wheel on the inside of the turn
B= track width
L= wheel base
b= distance from rear axle to centre of mass

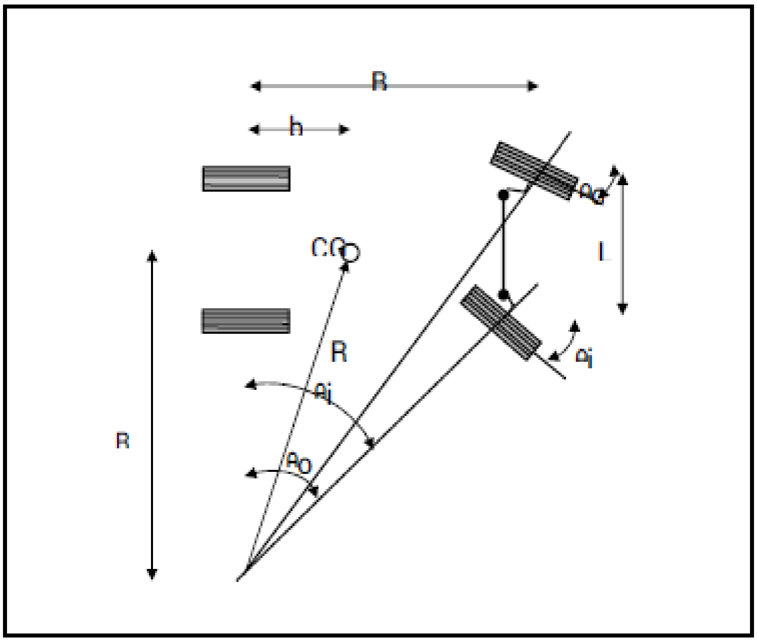


Figure 6.3: Ackermann Condition [7]

The proper alignment of a suspension/ steering system depends on the accuracy of the following:
– Caster
– Camber
– Toe
– Thrust line alignment
– Steering Axle Inclination (SAI)
– Turning radius
– Tracking
– There are host of gauges and electronic equipment to check and adjust these parameters.

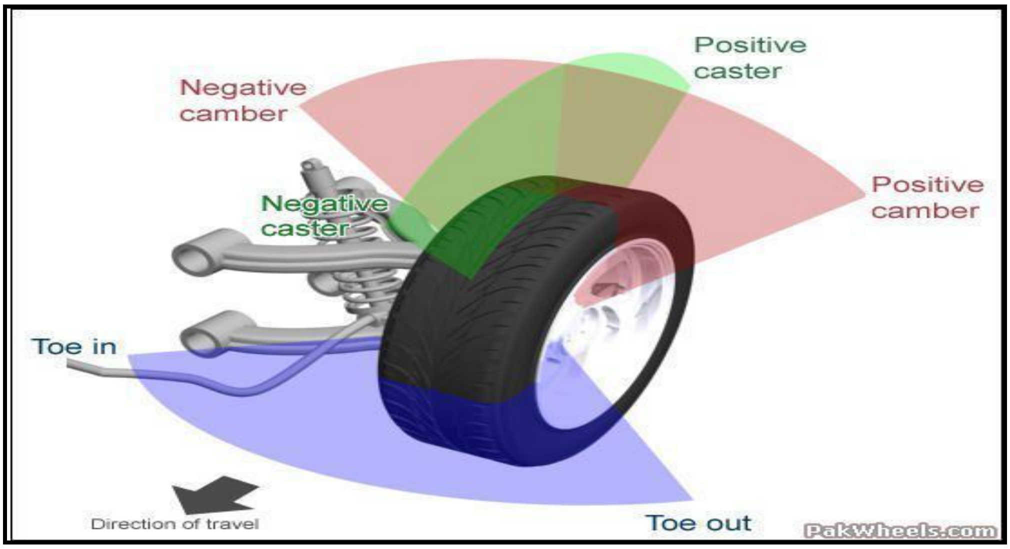


Fig.6.4 Alignment Geometry of Vehicle

6.2 CASTER

The caster angle is the angle between the pivot line and the vertical line at the centre of the wheel. The angle adds damping to the steering system as it controls the steering; too much caster angle makes the steering heavy. The caster can be positive or negative:

• **Positive**: If the top pivot is placed further to the rear than the bottom pivot –axis tilted forward.

• **Negative**: If the top pivot is placed further to the front than the bottom pivot –axis tilted backward.

Positive caster angle enhance straight-line stability when driving forward as it straightens the wheels. This happens because the steering axis, which points forward, pulls the wheel along when the car moves. As the caster angle is increased, camber gain can be achieved in corners. [7]

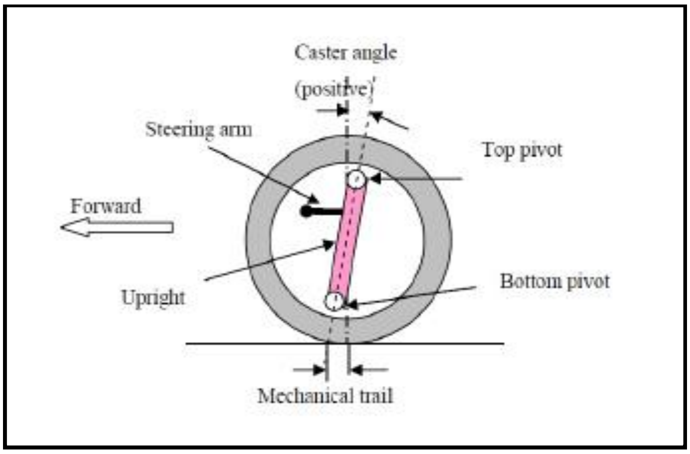


Figure 6.5 Caster Angle

– Is the angle of the steering axis of a wheel from the vertical, as viewed from the side of vehicle?
– It designed to provide steering stability.
– Caster is not related to tire wear.

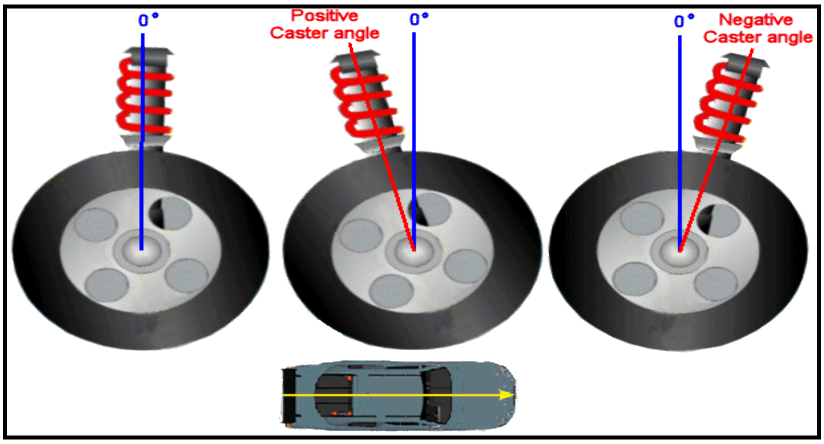


Fig.6.6 Caster Angle Geometry

6.3 CAMBER

The camber angle is the angle between the vertical axis of the wheel and the vertical axis of the vehicle. The angle is negative if the wheel leans towards and positive if it leans away from the chassis. [7]

The cornering forces on a wheel are dependable on the wheels angle on the road surface, and so the camber angle plays a major role on the forces acting on the car. It can also be used to increase the temperature in the wheels to their proper operating temperature by giving more negative camber angle. [7]

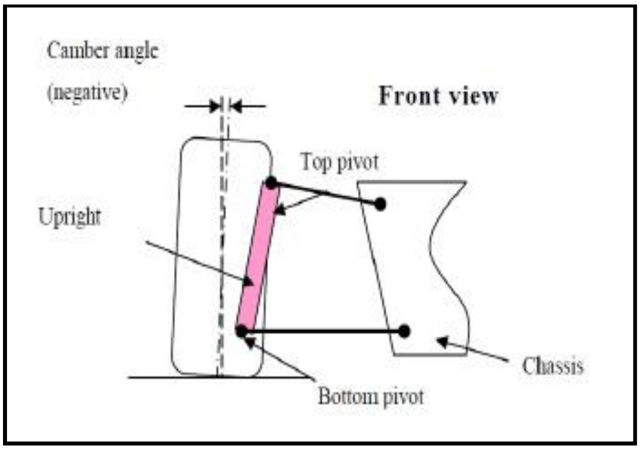


Figure 6.7: Camber Angle

– It is the angle represented by the tilt of either the front or rear wheels inward outward from the vertical as viewed from the front of the car.
– It is designed to compensate for road crown weight crown, passenger weight, and vehicle weight.

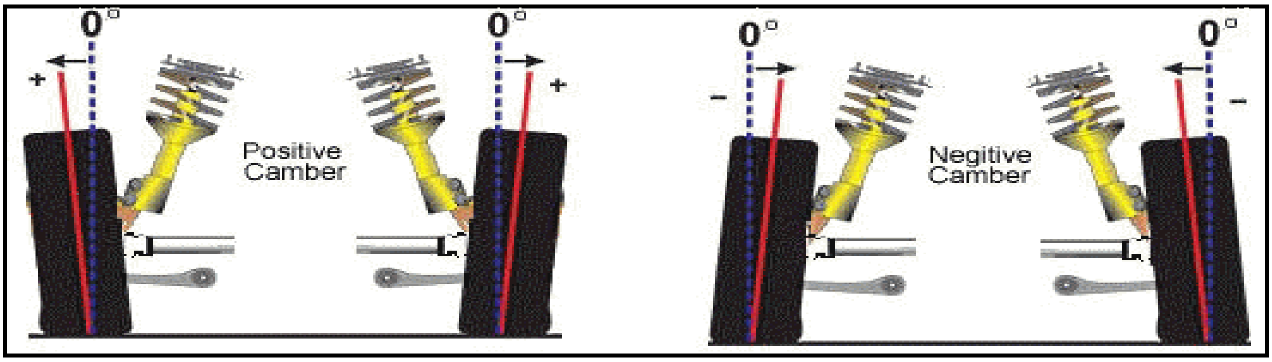


Fig.6.8 Camber Angle Geometry

6.4 TOE IN AND TOE OUT

The toe in/out configuration explains the position of the wheels relative to the neutral toe position where the distance between the front parts of the wheels equals the distance between the rear parts. The tie rods are adjusted to give the desired toe.

The toe configuration affects the handling of the vehicle and its performance on the straights and corners. Tire wearing will also be affected by the configuration chosen. By analysing the race track, the best decision of the toe configuration can be made.

• Toe in

In a "toe in" configuration, or positive toe, the front wheels are turned inwards giving a shorter distance between the front parts of the wheels and bigger distance at the rear parts. By increasing the "toe in" configuration, better stability can be achieved on the straights, but it will give less turning response in the curves. [7]

• Toe out

The distance at the front parts of the wheels are bigger compared to the rear parts. This is also called negative toe. The "toe out" position is more common in racing as the wheels are aligned in a position that encourages the initiation of a turn. The "toe out" may appear in five forms at the vehicle:

a) *Static "toe out"* - This is the "toe out" as a result of the adjustments of the tie rods. The tie rods are adjusted in a way that the wheels are "toed out".

b) *"Toe out" due to the tie rods configuration*- By using a shorter tie rod on the front left side compared to the front right side, the left wheel is steered at a larger angle than the right wheel when turning to the left. However, when turning to the right, this configuration will give a "toe in" position.

c) *Toe out on Ackerman steering*- When using an Ackerman configuration, the "toe out" will occur when turning the wheels. This means that the toe out due to the Ackerman configuration only occurs in turns.

d) *Toe out due to bump steer*- When riding, the ride motions and the body roll can lead to toe out.

e) *Toe out due to slip angles*- As the vehicle is turning, the outside contact patch between the wheel and the road will experience heavier load than the inside contact patch which result in a larger slip angle for the outside patch than the inside patch. As a result, the contact patches can be toed out. [7]

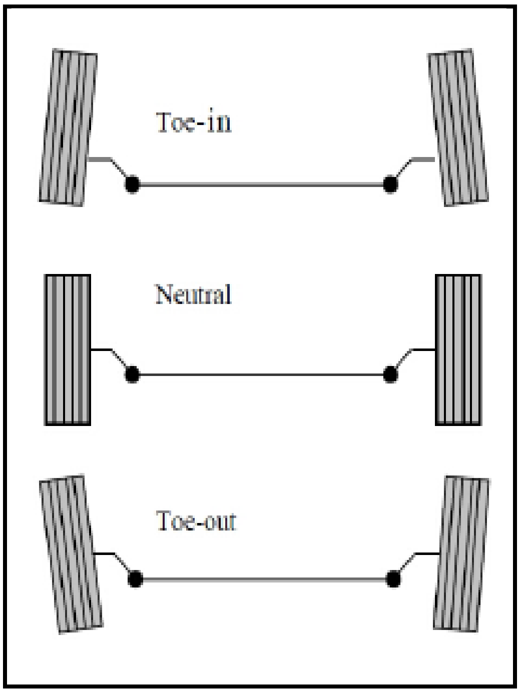


Figure 6.9 Diagrammatic representations of toe in, toe out and neutral conditions

– It is the distance comparison between the leading edge and trailing edge of the front tires.
– If the leading edge distance is less, then there is toe-in.
– If greater, it is toe-out.
– Toe is critical as a tire wearing angle.
– Wheels that do not track straight ahead have to drag as they travel forward.

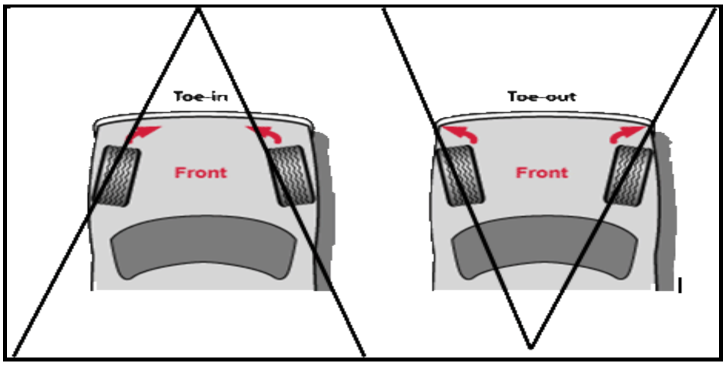
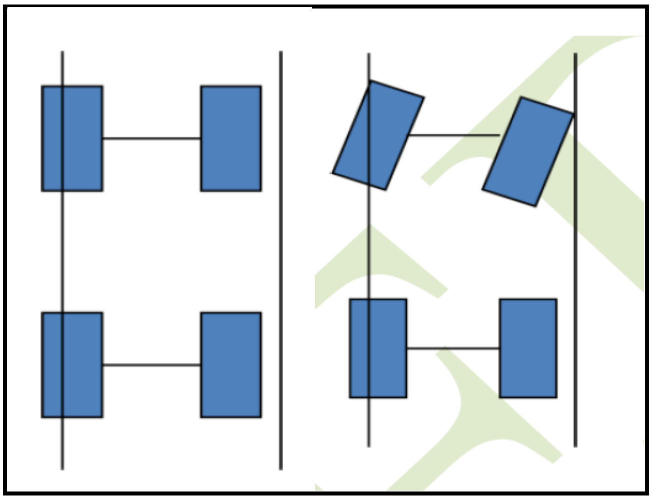


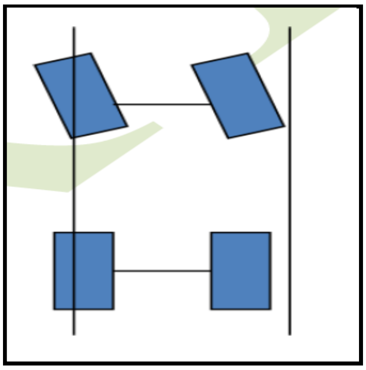
Fig.6.10 Toe in & Toe Out Angle Geometry

6.5 STEERING CONDITIONS:

Normal steering

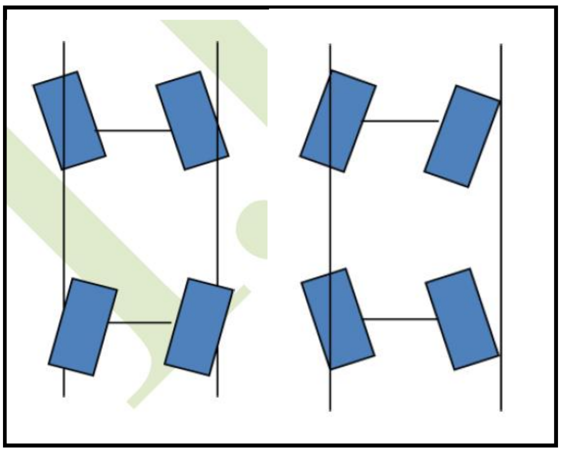


Idle position Right turn



Left turn

Four-wheel steering



Extreme left Extreme right

6.6 TURNING RADIUS

– Is the amount of toe-out present in turns
– It is also called ‘toe-out on turns’ or ‘turning angle’
– As the car goes round the corner, the inside tire must travel in a smaller radius circle than the outside tire
– This is accomplished by designing the steering geometry to turn the inside wheel sharper than the outside wheel
– This toe-out eliminates the tire scrubbing on the road surface by keeping the tires pointed in the direction they have to move

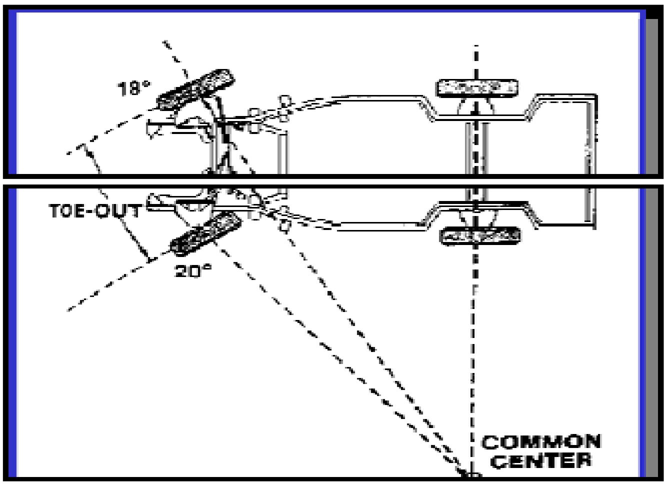


Fig.6.11 Turning Radius Geometry

6.7 LINKS

– Depending on the design application, can be referred to as –
- • Centre link
- • Drag link
- • Steering links

– Their purpose is to control sideways linkage movement, which changes the wheel directions.

6.8 TIE RODS

– Are usually assemblies that make final connections between the steering linkage and steering knuckle.
– They consists of-
- • Inner tie-rod ends, which are connected to the opposite sides of the centre linkage
- • Outer tie-rods, which are connected to the steering knuckle.

• They also have provision for varying lengths for correct settings.

6.9 BUMP-STEER

If the vehicle experience bumps on the track, the wheels may have the tendency to steer themselves without the driver doing any changes to the steering wheel. This is undesirable and known as bump-steer. The wheels will change between toe out and toe in as the suspension compress and de-compress during the bump. The steering wheel must be moved constantly to keep the vehicle in a constant turn. The wheel will also tend to toe out in a sharp turn as some of the weight is distributed to the outer wheel and hence makes the suspension on the outer wheel to compress. Bump-steer will also cause increase tire wear.

Bump-steer can be avoided by designing the same length and angle on the tie rod and the lover a-arm, and by ensuring that they both travel along the same arc during a bump. By comparison; if the tie rod got a shorter length, the travelling arc would also be shorter. The shorter arc would pull on the wheel and make it toe in during a bump.

It can also be controlled by introducing shims on the connection point between the tie rod and the bolt, which will increase the elimination of the toe experienced. However, it is important that the size of the shims is within the limit of what the bolt can handle, as the shim introduces a moment to the bolt when the lateral force is acting on the tire. The bigger the lateral force, the smaller the shim should be to avoid big moment on the bolt. [2, p. 22]

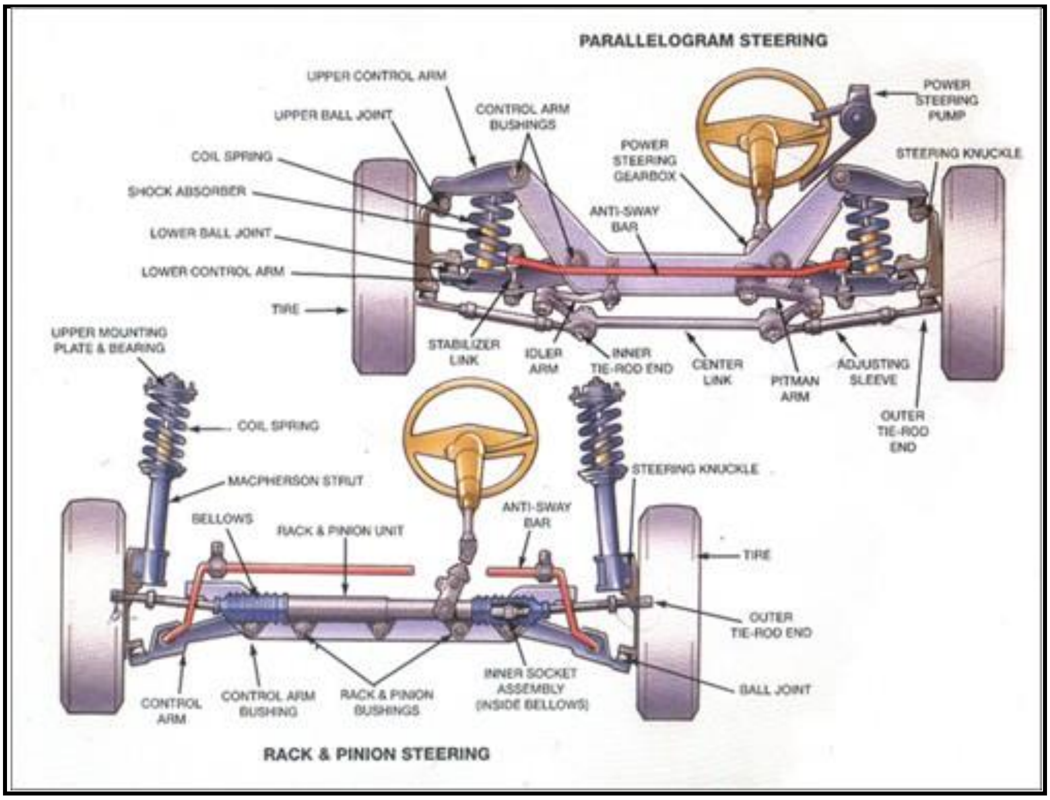


Fig.6.12 Rack and Pinion Steering Geometry

CHAPTER-7
DESIGN, CALCULATION & ANLYSIS

7. CALCULATION

The geometry validation was done by performing the analytical treatment. The concept of reverse engineering was applied in order to validate the designed geometry.
The following calculations were performed in order to validate the geometry:
Required condition is:

7.1 ACKERMANN GEOMETRY

Angle of inside lock (θ) = 30^0
According to Ackermann Geometry for perfect steering is given by:

$$\text{Cot } \Phi - \text{Cot } \theta = b / l$$

$$\text{Cot } \Phi = \text{Cot } \theta + b / l$$

$$\text{Cot } \Phi = \text{Cot } (30) + 1346/1752$$

Hence rearranging and substituting values in above equation;
(Φ) = 21.80^0
Also,
Inner Turning Radius,
(R_{if}) = l/sin θ= 1752/ sin (30)
(R_{if}) = 3504 mm

Outer Turning Radius,
(R_{of}) = l/sin Φ= 1752/sin (21.80)
(R_{of}) = 4717.69 mm

Hence by comparing both graphical and analytical data we can conclude that the both values are converging thus, the system designs accurate.

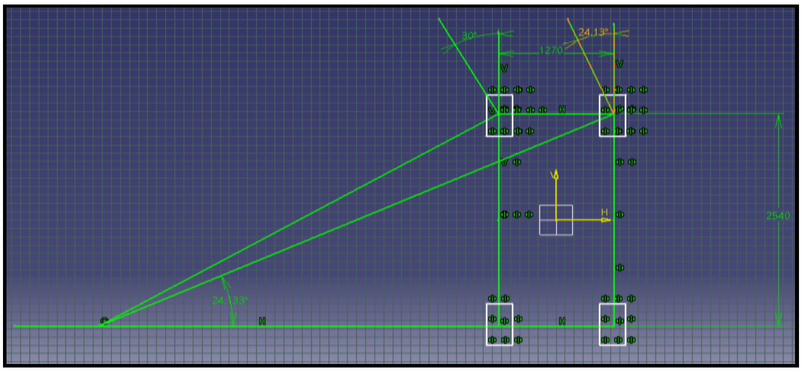


Fig.7.1 CATIA Model of Steering Angle Geometry

7.2 SELECTION OF GEAR TOOTH PROFILE

A gear tooth profile was selected based on BIS (Bureau of Indian Standard) recommendation and the manufacturability. A 20° full depth involute profile system was selected because of the following advantages:
It reduces the risk of undercutting
It reduces the interference

Due to increase in pressure angle, the tooth becomes slightly broader at the root this makes the tooth stronger and increases its load carrying capacity. It provides better length of contact. The properties of teeth of 20° full depth involute profile system are as follow:

Minimum number of teeth on pinion:
The minimum number of teeth required on pinion in order to avoid the interference was computed using following relation:
$Z_p = 2h_a/m.\sin^2\Phi$

Substituting values in above equation;

$Z_p=2h_a/m.\sin^2\Phi$
$= 2/ \sin^2\Phi$
$Z_p =17.09=18$

Hence minimum numbers of teeth on pinion are: 18.

Some other details of gear teeth profile are given below,

- Module = 2
- 20° full depth involute system ϕ =20°
- Addendum = h_a = 1m = 2mm
- Dedendum = h_f = 1.25m = 2.5mm
- Clearence = C = 0.25m = 0.5mm
- Working Depth =2m = 4mm
- Whole Depth =2.25m = 4.5mm
- Tooth thickness = 1.5708m = 3.14mm

7.3 STEERING RATIO

The steering ratio is the ratio of how much the steering wheel turns in degrees to how much the wheel turns in degrees.
Approximating maximum turn to be of 25 degrees and steering wheel movement to be 180 degrees the steering ratio can be calculated as,

S.R =180/25
=7.2

7.4 RACK TRAVEL

Once the steering ratio has been calculated the rack travel needs to be decided.
The steering wheel decided is AIM Formula steering wheel 2 which has a radius of 130 mm.
The steering wheel travel for one complete rotation,

$$=2\pi \times r$$
$$=0.6911m$$

Considering maximum steer angle and max rack travel is reached at complete rotation of the steering wheel.

The steering ratio can be equated to steering wheel travel/rack travel

$$7.2=0.6911/\text{Rack travel}$$
$$\text{Rack travel}=95.98 \text{ mm}$$

Therefore, required rack travel is around 96 mm.

7.5 RACK POSITION

The rack can have two positions. It can either be in front of the front wheel center line or behind it. If the rack is placed forward of the front axle line it can be mounted easily on the frame giving wide range for choice of heights. However, this arrangement makes it difficult to have the steering rack, track rods and steering arms in a straight line which is required if Ackermann geometry is a goal for steering design. Fixing the rack behind the axle line is better from both a geometrical and packaging viewpoint. Hence it is decided to have the rack positioned behind the front axle line i.e. a rear steer is chosen.

Fundamental Design Calculations

Ackerman angle

The Ackerman 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 radius. The Ackerman angle is very important in designing the steering components. We have two components moving together – the left and right steering knuckles, but the relationship between their motions changes as we move them.

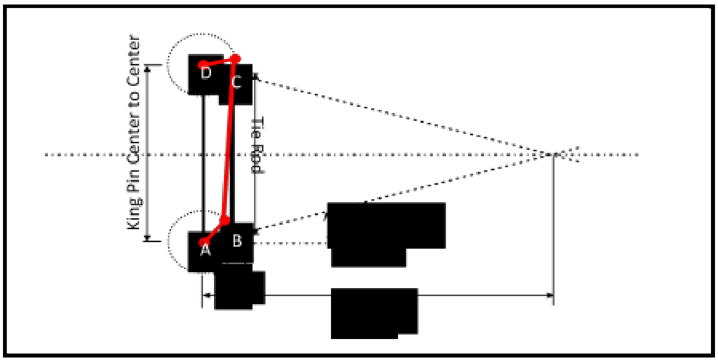


Fig.7.2 Ackermann Angle [7]

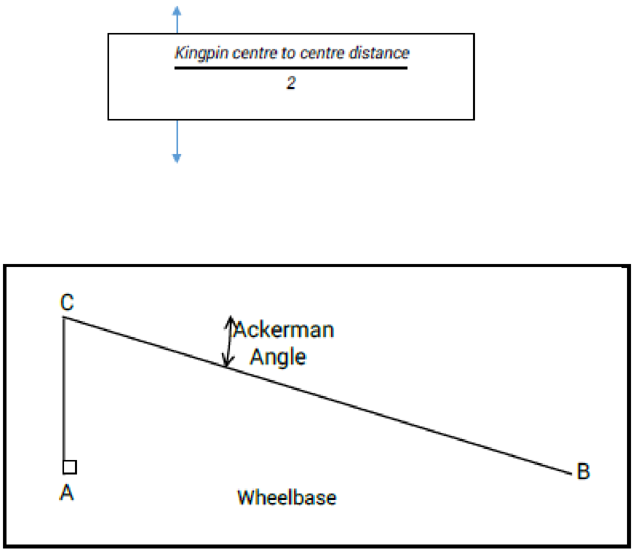


Fig.7.3 Relation of Ackerman angle, wheel base and kingpin centre to centre distance [7]

King Pin centre to centre distance =1350mm

Wheel Base = 1750mm

Vehicle weight without driver = 172.5Kg

Vehicle weight with driver =292.5Kg

So,

Ackerman angle,

$$\tan \Phi = \frac{\text{kingpin centre to centre distance}/2}{\text{wheel base}}$$

$$\tan \Phi = \frac{1350/2}{1750}$$

$\Phi = 21.09^{\circ}$

The Ackerman angle is calculated as 21.09°. This angle is implemented into the design so as to make sure the inner and outer front wheels do not turn at the same angle so as to prevent slip which will wear down the tyres really fast and reduce the speed of the car during cornering.

Determining the displacement of the rack

The lock to lock angle of the tires was agreed to be 70° which meant that when the tires are pointing straight ahead, the maximum deflection of the inner tires is 35°. Since the tie rod pushes the steering arm on one side and the other side is fixed, we can determine the displacement of the rack for a 35° deflection.

The length from the fixed point to the tie rod connection is assumed to be 100 mm.
r = 100 mm

Therefore,
Displacement $= \frac{35}{360} \times \pi \times 200$ mm
= 61.08mm

Therefore, to make an angle of 70° the rack has to be twice that length since the pinion will be at the middle of the rack.
Hence:
Rack length = $61.08 \times 2 = 122.17$ mm ≈ 130 mm

Pinion circumference

Pinion circumference = π × module × number of teeth
Where:
Number of teeth = 18
Module=2
Pinion circumference = $\pi \times 2 \times 18$
= 113.09
= 120

Calculation of Forces and Torques

Force Required to Turn the Tyres

The frictional force caused by the contact between the ground and tyre is transmitted from the tyre, through the steering arm, to the tie rod, all the way to the rack and pinion and finally to the steering wheel where the driver has to overcome this frictional force so as to make the wheels turn. The force that is transmitted is destructive to the mechanical components and can cause failure.

To prevent failure, the force is calculated and the components are designed to withstand such forces.

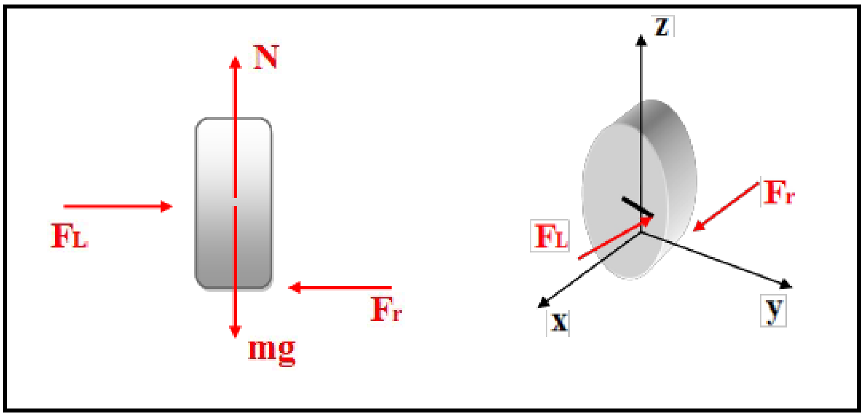


Fig.7.4 Forces on the wheel

F_r = friction force
mg = weight
F_L = lateral force applied from the steering wheel
N = normal reaction

The wheel rests on the ground on a surface and not in a point so it appears with two friction forces as we can show in the figure below.

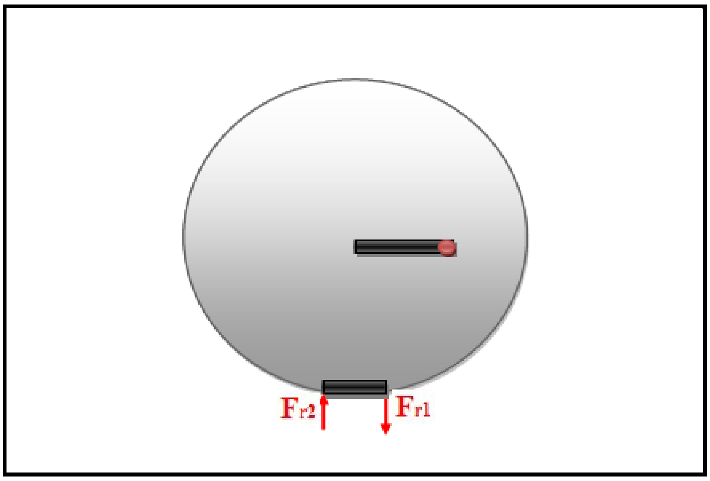


Fig.7.5 Application of frictional forces on the wheel

In the diagram above shows a section of wheel. The black rectangular section at the centre of the wheel is the position of the steering arm, with the red dot being the application point of the lateral force from the steering wheel. The distance between the red dot and the middle of the wheel is the steering arm length (R_s). The small black rectangular section at the bottom represents the contact surface between the wheel and the ground, with Fr1 and Fr2 being the friction forces that occur on the contact surface of the wheel. These forces act on a radius r from the middle position of the wheel.

Fr1 and Fr2 act in different directions but they are of the same magnitude and under the same moment. Thus we can say:

$$F_{r1} = F_{r2} = F_r$$

Adding up the horizontal forces:

$\Sigma F_x = 0,$ $\quad F_L - F_r = 0$

$\quad F_L = F_r$ (1)

Adding up the vertical forces:

$\Sigma F_y = 0$ $\quad N - mg = 0$

$\quad N = mg$ (2)

Summing up the moments about the centre of the wheel:

$\Sigma M_y = 0$ $\quad (F_L \times R_s) - (2 \times F_r \times r) = 0$ (3)

Since this project is limited to the steering system and the other parts of the car are not designed, the weight of the car is assumed.

A typical solar electric car usually weighs 172.5 Kgs and the driver and one passenger can weigh about 120 Kgs.

Therefore, the total mass is

$$(172.5 + 120) \text{ Kg} = 292.5 \text{ Kg}.$$

To calculate the weight distribution on each tyre, the weight ratio for front to back was taken to be 40:60. That means that the front tyres takes only 30% of the total weight of the car. Therefore, the mass on the front tyres is:

$$292.5 \times \frac{40}{100} = 117 \text{ Kgs}.$$

The mass exerted on one tyres will be half of the 117 Kgs which is 58.5 Kgs.

Hence the weight will be:

$$58.5 \times 9.81 = 573.885 \text{ N}$$

F_r may be found using the following formula:

$$F_r = \mu \times N$$

Where: μ = friction coefficient

$N = mg$

The friction coefficient will be of a higher value in order to establish a safety coefficient. So we take $\mu = 1$.

Now we calculate the friction force:

$$F_r = \mu \times N$$
$$= 1 \times 573.885N$$
$$= 573.88N$$

And from equation (1)

$$F_r = F_L$$

Thus:

$$F_L = 573.88N$$

This is the force that the rack has to transmit to the tie rods and these to the steering arms to move the wheel. According to the conditions given, this will be the minimum force required to cause a turn of the wheels. But since the friction coefficient was rather large, we can assume that this is the force that will be applied by the driver during racing.

Now we can calculate the torque on the pinion. To calculate the torque, we use the following equation:

$$T = F \times r_{pinion}$$

In our case we have a pinion with a diameter of 18 mm so:

$$T = 573.88 \times 18$$
$$= 10329.84 \text{ N-mm}$$
$$= 10.309 \text{ N-m}$$

8. DESIGN AND ANALYSIS

Various software was used in the design of our steering system. This software was primarily used to visualize, manage and test the design without having to make the actual component or system.

A Computer Aided Design (CAD) and Finite Element Analysis (FEA) software were used in the design and testing of the steering system. The Computer Aided Design conceptualized the overall design of the steering system where the components and the working principle and movements of the steering system were projected. When the CAD design was complete, the finite element analysis tests followed. The finite element stress analysis, strain analysis and elastic deformation were then applied on the components. These tests were applied to the components that have an applied force which can cause elastic deformation or buckling.

8.1 Computer Aided Design

Computer aided design helped to aid in the creation, modification, analysis and optimization of the design. CAD software is used to increase productivity of the design, improve quality of design and communications through documentation and to create a database for manufacturing. The design process is an iterative procedure as shown in the figure below.

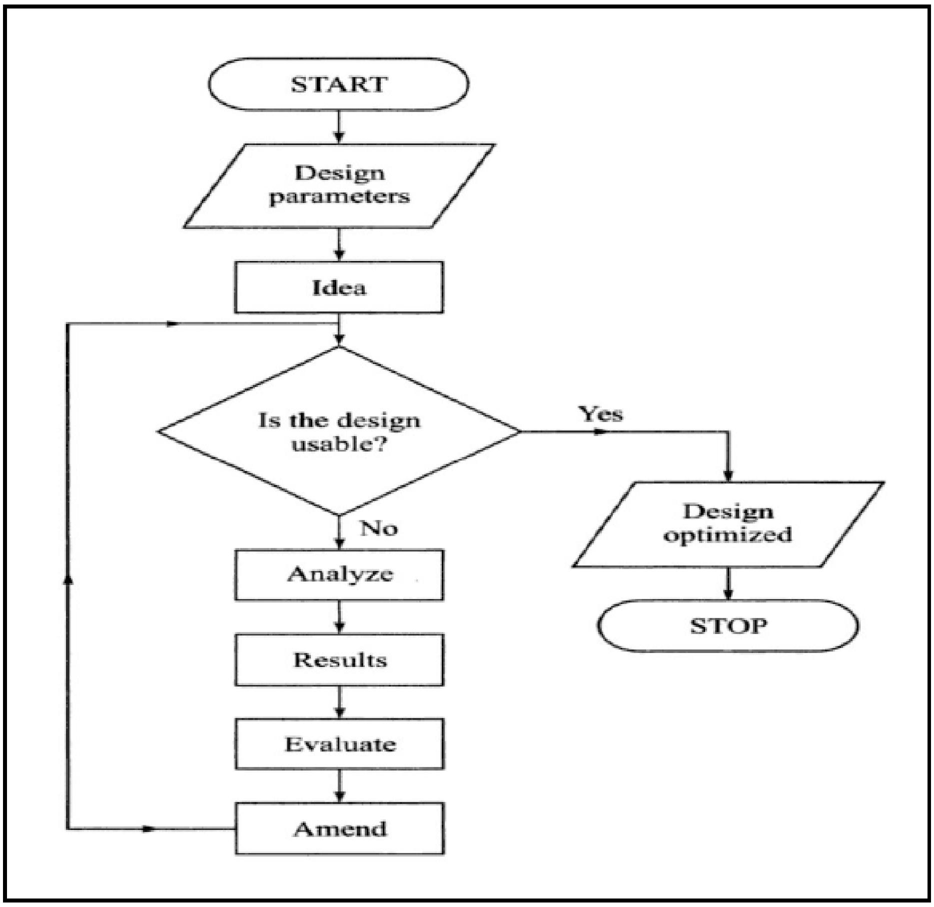


Figure 8.2: Computer Aided Design process

The mechanical engineering CAD software used is the SOLIDWORKS software. The Figure below shows the conceptual design: -

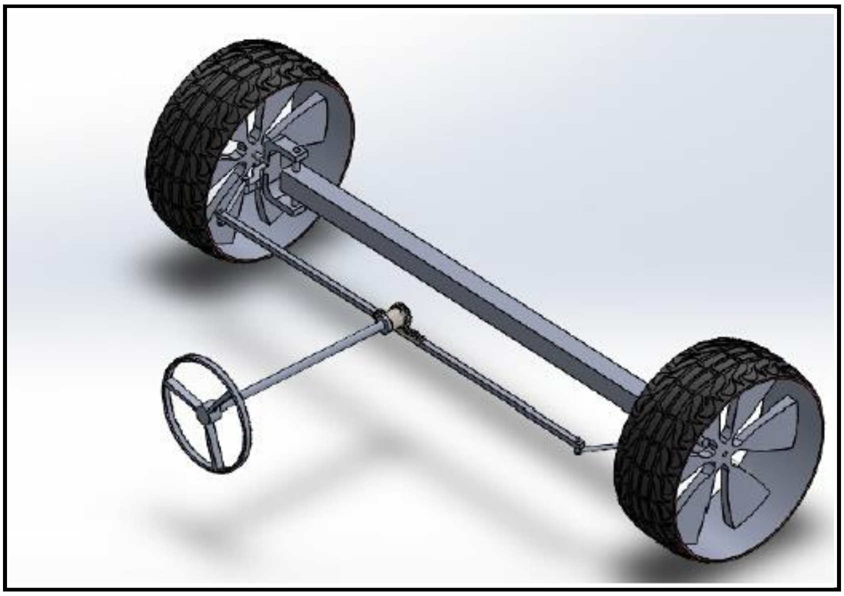


Figure 8.3: Isometric view of the simulated steering system

The CAD design shown above consists of the original design of a rack and pinion steering that can be used in a Formula One student race car. The system uses the Ackermann principle which accounts for the turning radius and wheel angle. The dimensions used to make the computer model were obtained from the calculations in chapter Four.

8.2 Finite Element Analysis (FEA)

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real world situation like applying forces, vibration, heat, fluid flow, and other physical effects.

FEA subdivides a large problem into smaller, simpler, parts, called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem.

In the process of analysis, the parts are broken down to three main parts i.e.

- Elements
- Nodes
- Meshes

In stress analysis the equations are equilibrium equations of the nodes. There maybe several hundred or several thousands of these equations hence computer implementation is mandatory.

The finite element analysis was conducted using the ANSYS Mechanical software program. The software is a finite element analysis tool used for structural analysis, including linear, nonlinear and dynamic studies. The computer simulation provides finite elements to model behaviour, and supports material models and equation solvers for a wide range of mechanical design problems.

The software was used to test for any structural deformations like buckling, directional deformation, equivalent stresses and equivalent elastic strain.

Test Procedure

The following are the necessary steps used to test using ANSYS software:
• Meshing the components
• Applying forces and pressures.
• Fixing non-moving faces.
• Applying magnitude of forces.

The components to be tested had already been designed and were easily imported from SOLIDWORKS CAD. The components put under test are as follows: -
• Steering arm
• Tie rod

We are using rack and pinion mechanism because of oblivious advantages of reduced complexity, ease of construction and less space requirement compare to other steering mechanisms. The analytical steps involved in designing if rack and pinion systems areas follow:

8.3CAD MODEL OF RACK AND PINION

We have designed complete assembly of rack and pinion in SOLIDWORKS 2015, the complete design of rack and pinion and its assembly in SOLIDWORKS 2015 is shown below:

Fig.8.4 Cad model of Rack and Pinion in SOLIDWORKS

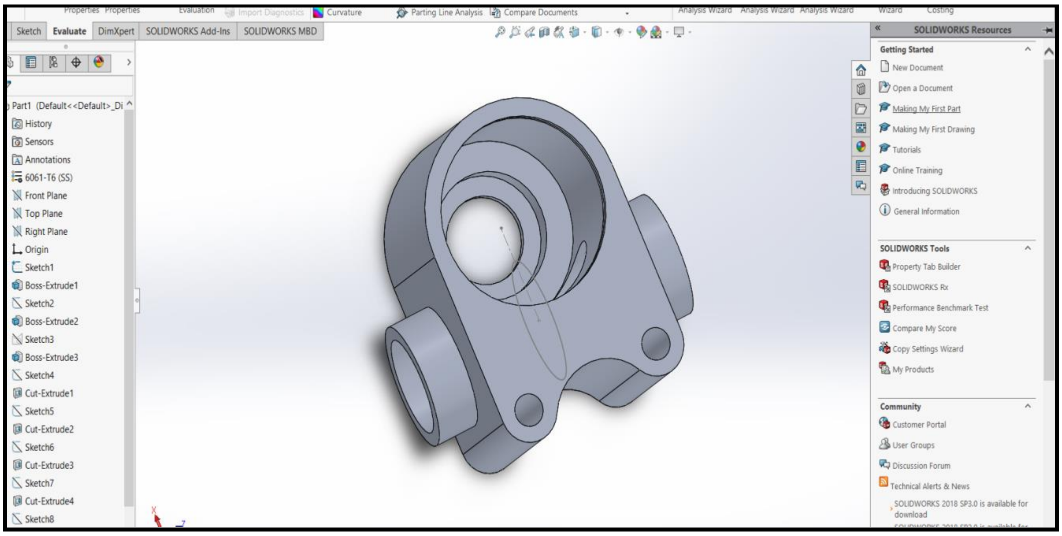


Fig.8.5 Cad model of Pinion casing in SOLIDWORKS

8.4ANALYSIS OF COMPONENTS

Analysis is process of analysing the components by applying load, temperature, pressure etc. and obtaining the values such as stresses (bending, tangential and normal), deformations, safety factor etc. in order to determine the safety of the components when done in practical. These Analyses gives optimum result of safety of components and minimize the chances of failure.

Three major analyses of rack and pinion on Ansys 15.0 are carried out here:
1) Total Deformation
2) Equivalent Stress
3) Factor of Safety

a) Total Deformation

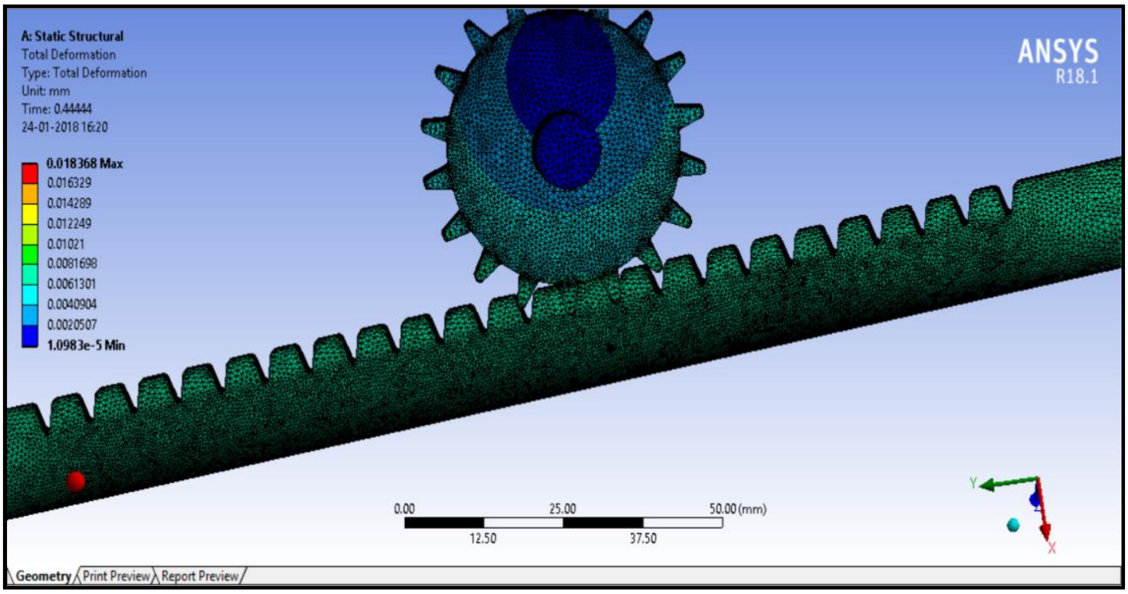


Fig.8.6 Total Deformation in Rack and Pinion

b) Equivalent Stress

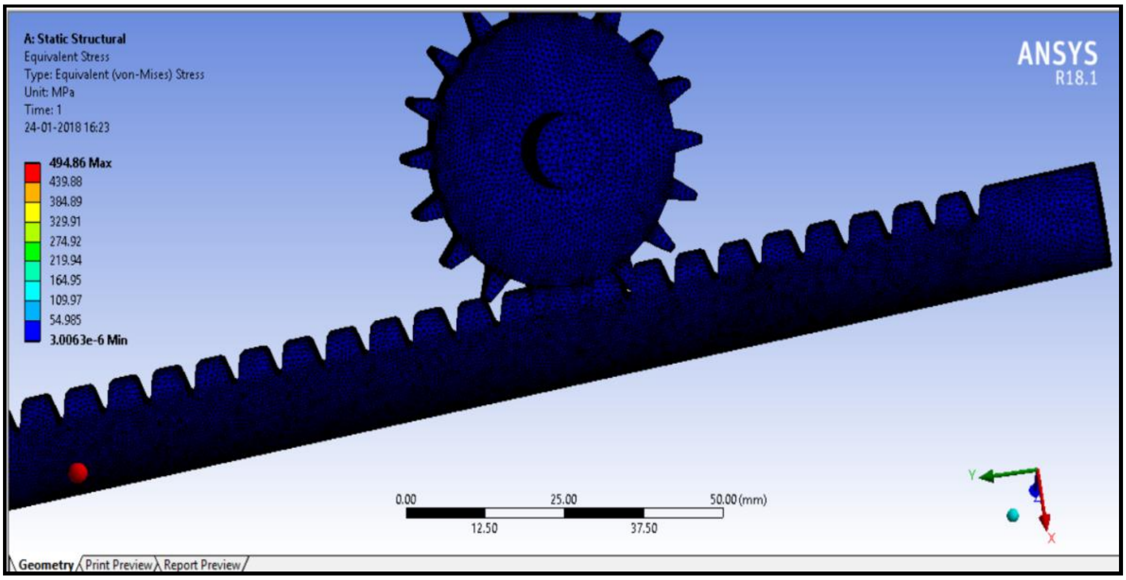


Fig.8.7 Stresses Generated in Rack and Pinion

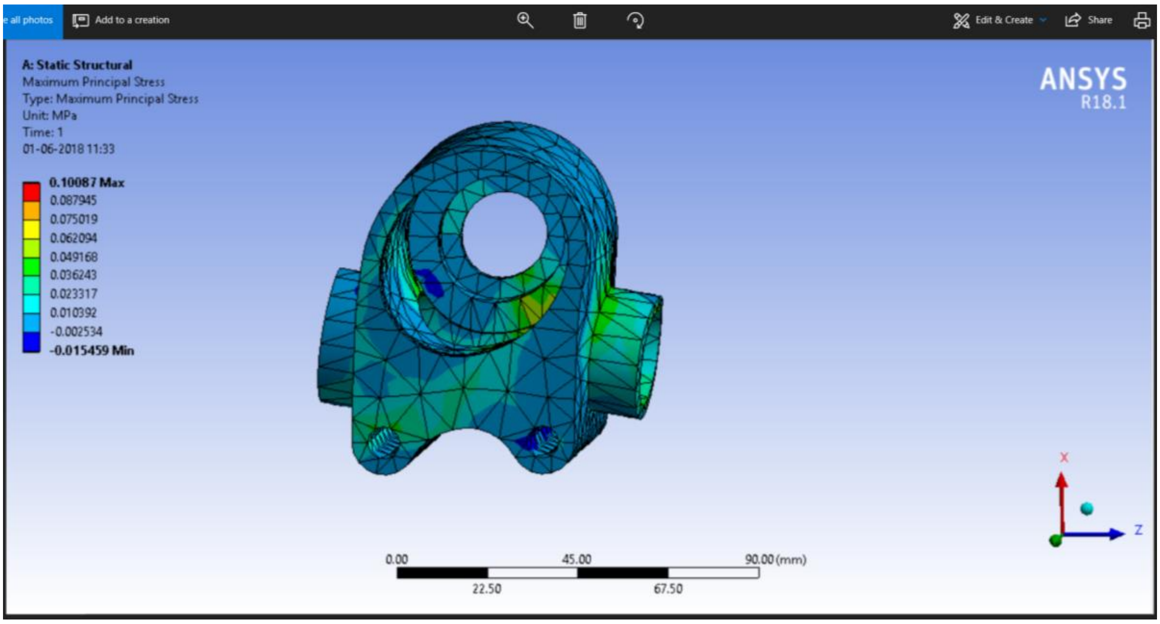


Fig.8.8 Stresses Generated in Pinion casing

- Material Type: EN 19 Alloy Steel
- Ultimate Tensile Strength = 850 MPa
- Maximum Stress Obtained = 18.845 MPa
- Factor of Safety = 15
- Maximum Deformation = 15.5757 x 10-4mm

Thus after the analyses of components The Design is Completely Safe.

9. CONCLUSION

Its Conclude that to improve the steering geometry i.e. reverse Ackerman geometry, which helps the driver to avoid the negative effect of cornering forces acting on vehicle &. Increases the space in cockpit area and the comfort of driver. Steering geometry can be optimized by using mathematical model for Ackerman condition for different inner wheel angles and select geometry for which percentage Ackermann as well steering effort is optimum. The composite material increases the strength of rack & pinion & reduces the weight of system which helps to reduce gross weight of vehicle. The weight Composite Material is reduced as compared to others material which is turn result in improved power transmission which overall improve the efficiency of the system.

Geometry	**Ackermann geometry**
Steering type	Rack & Pinion
Type of rack used	Centrally mounted
Steering ratio	7.2:1
Inner turning radius	3504 mm
Outer turning radius	4717 mm
Inner wheel angle	30 degree
Outer wheel angle	21.8 degree
Steering wheel travel	360 degree (691 mm)
Rack Travel	96 mm
Toe in (+ve)	1 degree
Camber angle	0 degree
Turning Radius	3.6 meter
Material for Rack and Pinion	EN-19
Material for Steering column	MS

Table 9. Steering results at a glance

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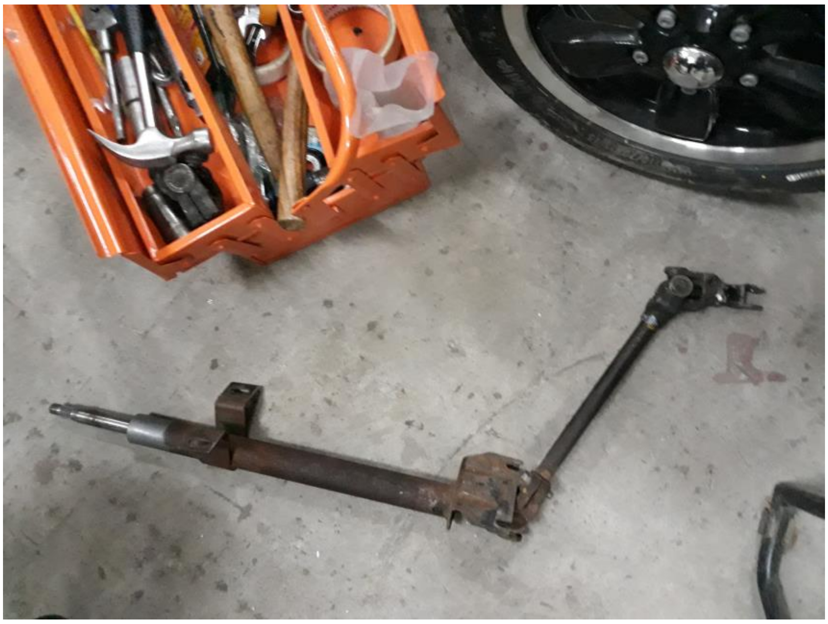
GALLERY



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Design of Steering Gear System in Passenger Car: A Review

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Abstract - rack and pinion steering systems are commonly used due to their simplicity in construction and compactness. The main purpose of this paper is to design and manufacture manual rack and manual pinion steering system according to the requirement of the vehicle for better manoeuvrability. Quantities like turning circle radius, steering ratio, steering effort, etc. are inter-dependent on each other and therefore there are different design consideration according to the type of vehicle. The comparison of result is shown using tables which will help to design an effective steering for the vehicle. A virtual rack and pinion assembly can be created using software's like SOLIDWORKS and ANSYS.

***Keywords**:* Ackerman Steering Geometry, Motion transmission, Rack and Pinion Housing and Tie Rod Assembly.

1. INTRODUCTION

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship or Boat) or vehicle to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide steering column, which may contain universal joints, to allow it to deviate somewhat from a straight line.

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.

The steering system acts a significant role of making car convenient to handle and enhance the vehicle stability. In the past one hundred years, the development of steering system has experienced many stages, and the Steer-by-Wire system (SBW) is the newest technology of steering system for passenger cars. But the Steer-by-Wire system has not yet accepted by public consumers and permitted by state regulations, in consideration of the reliability and safety of the system.

The steering system of a vehicle allows the driver to control the direction of the vehicle through a system of gears and linkages that connects the steering wheel with the front wheels. Steering Systems - Introduction The steering system must perform these functions:

- Change direction of vehicle.
- Provide a degree of 'feel' of the road for the driver.
- Not transmit excessive shock back to the driver due to an uneven road.
- Not cause excessive tire wear.

1.1 CONVENTIONAL STEERING SYSTEM

In this steering system, only the front wheels are steered towards right or left according to the requirement because at the rear their dead axle is present.

1.2 FOUR WHEEL STEERING SYSTEM

In this steering system, the all four wheels are to be steered according to the steer perform to drive towards left or right. Four-wheel steering, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. 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.

In most active four wheel steering system, the rear wheels are steered by a computer and actuators, the rear wheels generally cannot turn as far as the front wheels. Some systems including Delphi's Quadra steer [3] and the system in Honda's Prelude line allow the rear wheels to be steered in the opposite direction as the front wheels during low speeds. This allows the vehicle to turn in a significantly smaller radius sometimes critical for large tucks or tractors and vehicles with trailers.

1.3 ACKERMAN STEERING SYSTEM

According to Ackermann Steering geometry, the outer wheels moves faster than the inner wheels, therefore, the equation for correct steering is [8]:

$$\text{Cot}\,\Phi - \text{Cot}\,\theta = b / l$$

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