MACHINE DESIGN REPORT

On

Power Steering System using Rack and Pinion

By

Kush Patel (Roll No: 20BME081)

Bachelor of Technology
In
Mechanical Engineering
School of Technology

Pandit Deendayal Energy University

Gandhinagar – 382426, Gujarat, India

2023

PANDIT DEENDAYAL ENERGY UNIVERSITY

Gandhinagar 380 007, Gujarat

Department of Mechanical Engineering

Certificate

This is to certify that Mr. ***Kush Patel*** *Roll no.* **20BME081** *o f*

Odd Semester *of* ***3rd Year*** *B. Tech Degree in* ***Mechanical Engineering*** *has satisfactorily completed his Major Project Report in Machine Design-I subject atSchool of Technology, PDEU.*

Date of Submission:

Signature:

Faculty
In-charge
(Dr. Manjeet
Keshav)

Declaration

I declare that this written submission represents our ideas in our own words and where others' idea or words have been included, I have adequately cited and referenced the original sources. I also declare that we have adhered to all principles of academic honestly and integrity and have not misrepresented of fabricated or falsified any idea / data / fact / source in my submission. I understand that any violation of the above will be cause for disciplinary action by the PANDIT DEENDAYAL ENERGY UNIVERSITY.

Kush Patel

(Signature of the Student)

Specimen 'B': Approval Sheet

This report entitled "Power Steering System using rack and pinion" by Kush Patel is recommended for the credits of Major Project for Machine Design 1 Lab.

Sign of Examiners

____

____

Sign of Supervisors

____

Date: 27-04-2023

Table of Content

Chapter 1 : Introduction

Background of Study on rack and pinion

Machine designers have relied on rack and pinion gears for decades to transform rotary motion into linear motion. Rudimentary versions of the rack and pinion mechanism were utilised in water mills and other machinery in ancient Greece and China. Until the Industrial Revolution, rack and pinion were not commonly utilised in mechanical engineering, yet they were integral to the creation of steam engines and other forms of power generation.

The ease with which rack and pinion mechanism’s function is one of their primary benefits. In most cases, the rack will be a flat or round bar with teeth that mesh with a pinion. The rotation of the pinion propels the rack in a straight line. Rack and pinion mechanisms are well-liked because of their simplicity, affordability, and dependability.

Rack and pinion mechanisms are efficient, which is still another benefit. Since the pinion is often much smaller than the rack, a relatively modest quantity of rotational motion can be transformed into a substantial amount of linear motion thanks to the gear ratio. Because of this, applications that need for extreme accuracy and precision often favour rack and pinion mechanisms.

Rack and pinion mechanisms are useful in machine design for more than just their ease of use and efficiency. Their small size makes them perfect for smaller equipment. There are no belts or chains, thus they require less maintenance. Lastly, they provide superb motion control, making them a top choice for precision-oriented machinery.

When it comes to translating rotary motion into linear motion, rack and pinion systems are a versatile and dependable option. Used in anything from industrial robots and CNC machines to cars and steering systems, they've been around for quite some time. It's safe to assume that rack and pinion systems will continue to play a significant role in machine design even as technology advances.

The rack and pinion are just one aspect of the system; bearings, guides, and supports could all play a role. These components, which may be constructed of plastic, metal, or composite materials, are utilised to keep the mechanism running smoothly and reliably.

The rack and pinion system relies on only two main components, making it both simple and sturdy. Because of its ease of use and dependability, it is widely implemented in everything from computer numerical control equipment and industrial robots to cars and steering systems. Different varieties of rack and pinion mechanisms are more suited to certain tasks than others.

Some of the most typical examples are as follows:

The simplest rack and pinion mechanism consists of a rack (a straight bar) and a pinion (a tiny gear that meshes with the rack's teeth). Common uses for straight rack and pinion mechanisms include steering systems and linear actuators because of their simplicity and dependability.

The rack teeth in a helical rack and pinion are cut at an angle to form a helical pattern. A helical pinion gear meshes with the rack's teeth for quieter, more efficient operation than conventional straight rack and pinion systems. Applications like computer numerical control (CNC) machines rely heavily on helical rack and pinion mechanisms due to their precision and reliability.

Third, we have the circular rack and pinion, which differs from the straight rack and pinion in that the rack is bent in a round shape. When the pinion gear engages with the rack's teeth, it spins the rack in a circle. Steering systems and rotational actuators are two common uses for circular rack and pinion mechanisms.

The fourth form of rack and pinion mechanism is the double rack and pinion, which employs two racks in tandem and has a single pinion gear that drives both racks. Common uses for double rack and pinion mechanisms include lifting systems and other heavy-duty applications.

5. Crossed Rack and Pinion: In this configuration, the pinion gear drives two racks that are positioned at right angles to one another. When both linear and rotational motion are needed, like in gantry systems, a crossed rack and pinion mechanism is utilised.

In general, rack and pinion mechanisms come in a wide variety of forms, each of which is better adapted to a specific task. Engineers can improve the effectiveness, accuracy, and dependability of their machines by carefully selecting the appropriate mechanism for each task.

Electric Power Steering (EPS)

In an electric power steering (EPS) system, the output of an electric motor is directly transferred to the steering system, lowering the amount of effort needed to operate the vehicle. Incorporating an EPS boost curve into the assist features is the goal of this study in order to improve the steering's maneuverability and steadiness. There have been produced models for the mechanical components of the complete vehicle, the EPS system, and the EPS electric control system. A straight-line boost curve was created and tested using this model in order to improve the EPS system's performance in this situation. The findings showed that by reducing reacting time and overshoot value, the EPS system with the modified boost curve ensured dynamic reactivity and stability.

For the control and stability of the vehicle, the electric power steering (EPS) system is essential. An EPS system, which consists of a mechanical subsystem and an electronic and control subsystem, must be compatible with the complete mechanical system of a vehicle. The EPS system's many subsystems must be developed simultaneously to reduce development time and costs. Together, engineers must develop a variety of subsystems.

Model-based development is a sensible strategy because of this requirement for concurrent development and interaction.

Electric power steering (EPS) systems are essential for improving a vehicle's control and stability. An EPS cannot work and integrate with the rest of the vehicle's mechanical configuration without the mechanical, electronic, and control subsystems. The EPS system's many subsystems must be developed simultaneously to reduce development time and costs. Together, engineers must develop a variety of subsystems. Model-based development is a sensible strategy because of this requirement for concurrent development and interaction.

The electric control system, which interprets information from speed, steering angle, and steering torque sensors to deliver torque to the assist motor as necessary, is an essential part of the EPS. This control system's difficult task is to include the assist feature in a boosting curve. Most EPS research has centered on the subject of regulation. Numerous facets of aid have not received enough research.

The use of models in the development of the EPS system has been studied. The EPS system has been included in models of whole mechanical vehicle systems. A straight-line boost curve was devised and put to the test in order to optimize the EPS's performance in this situation.

In order for the assistant motor to provide the required help torque, the electric control system must first receive data from the vehicle's speed, steering angle, and steering torque sensors. The key to this control technique is finding a boosting curve that captures the assist characteristic. Most EPS research has centered on the subject of regulation. There is no formal mechanism for establishing the steering aid value other than watching its impact on the road; just a selection of assist features is analyzed; a boost curve is supplied. The use of models in the development of the EPS system has been studied. A thorough mechanical vehicle system has been used to model the EPS system. A straight-line boost curve was devised and put to the test in order to optimize the EPS's performance in this situation.

The most typical form of steering system is a rack and pinion, which is used in 80% of commercial vehicles. This one is the easiest to sketch up and requires the fewest parts. A rack and pinion linear actuator use two gears to convert rotary motion into linear motion. The rack travels in relation to the pinion when rotational motion is applied, translating the rotational action into linear motion. The rack is a linear "gear" bar, while the pinion is a circular gear with teeth on it.

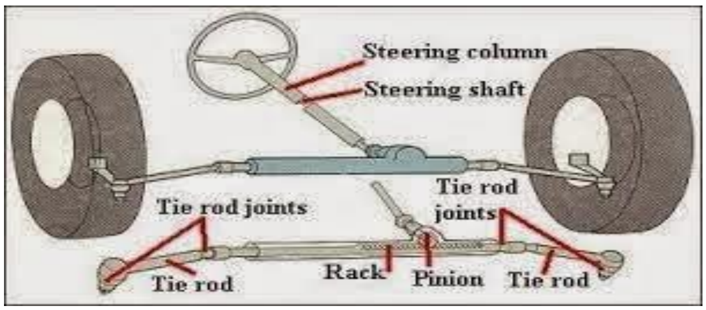

Figure 1 Steering Mechanism

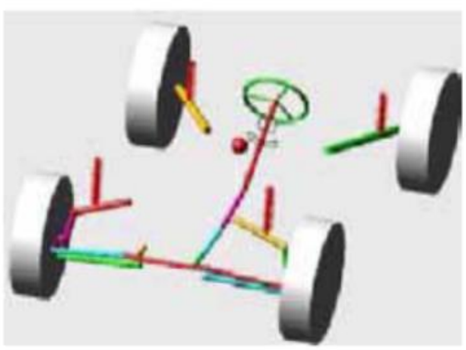

Figure 2 Full vehicle's mechanical system model

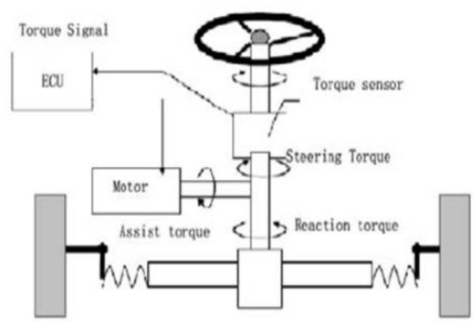

Figure 3 A steering Mechanism with EPS

The system-level model includes a mechanical subsystem model for a full vehicle, and for steering system in detail. This mechanical model for the full vehicle and the steering system is established in the software. It includes suspensions for the four corners. The steering system's mechanical model includes steering wheel, steering column, steering rack/pinion, and some connection poles. The chassis model is coupled with the road surface by tire model, which is built based on the module. This method is used in vehicle dynamics modeling, and the full vehicle model. The model consisted of 15 degrees of freedom, including 6 for vehicle body, 2 for front suspension, 2 for rear suspension, 4 for wheels and 1 for steering wheel

EPS subsystem model is described by the angular rate and position of the steering column and motor, the linear velocity and displacement of the steering rack. Fig. 2 shows the schematic diagram of a steering mechanism equipped with EPS. It can be formally subdivided into three subsystems:

The electronic control unit (ECU) with related sensors such as the steering torque, steering angle sensor, and motor current sensor; the mechanical steering system consisting of the wheel, column, torsion bar, and rack; and the brush-type direct current (DC) motor, which provides assisting torque. Following is a brief synopsis of the primary way of operation. When the driver turns the wheel, a steering torque is generated and applied to the torsion bar, which in turn moves the steering rack. Changing the position of the steering rack, and hence the rack force, induces a corresponding change in vehicle direction. A portion of the rack force is counterbalanced by the servo force generated by the auxiliary motor to aid the driver and create a good steering sense.

Depending on the make and model, power steering parts can come in a wide range of sizes. However, here are some broad principles to follow:

As for the power steering pump, it has a standard size of 6-8 inches in length and 4-6 inches in diameter.

The reservoir for the power steering fluid can range in size from a few inches in diameter and length to a few feet in either direction.

Power steering hoses are available in diameters between 3/8 inch and 5/8 inch and can be as long as several feet.

The rack and pinion used for power steering can range in size from four to five inches in height, two to three inches in width, and many feet in length.

The diameter of the power steering control valve can be between 3 and 4 inches, and its length can range from 6 to 8 inches.

These are just rough estimates, and the actual measurements may be different depending on the power source you use.

Chapter 2: Literature Review

Practical Applications

Simple, dependable, and providing precise motion control, rack and pinion systems find widespread use in a variety of sectors. The following are some typical applications for rack and pinion systems:

Vehicles of all shapes and sizes employ rack and pinion systems for steering, including cars, trucks, and even trains. The rack is fastened to the car's front wheels, while the pinion gear is connected to the steering shaft and rotates with the wheel. The wheels and the ability to steer the vehicle are turned by the pinion, which is driven by the rotation of the shaft.

Computer numerical control (CNC) machines use rack and pinion systems for the precise and consistent motion control they require. A CNC machine's rack and pinion system allows for highly accurate control of the cutting tool's location and movement along the machine's X and Y axes.

Third, rack and pinion systems find extensive application in industrial automation, particularly in linear actuators and robotic arms. These technologies allow for very accurate and repeatable mobility in robots and other automated machinery.

Lifting systems: Lifting systems, including lifts and steering, frequently employ rack and pinion systems. The rack is driven by a pinion gear, allowing the platform or load to be raised and lowered with great precision.

Gantry systems are enormous machines used for cutting and shaping materials like wood and metal, and they use rack and pinion systems. The cutting head can move in two dimensions and make intricate cuts and shapes thanks to the crossing rack and pinion gear, which controls linear and rotational motion.

Rack and pinion systems can be found in a variety of fitness devices, including rowing machines and treadmills. User comfort and control are ensured by a pinion gear connected to the flywheel or motor and a rack that moves the seat or running surface. In general, rack and pinion systems are dependable devices utilized in many different contexts, including car steering, industrial automation, and even exercise equipment. Because of their simple construction and accurate motion control, they are widely used in a wide variety of machinery.

Vehicles with power steering need the driver to exert less force when turning the wheel. The vehicle's wheels are turned with the help of hydraulics or electricity, making it easier for the driver to steer.

Here are some real-world examples of how power steering might be useful.

- Power steering systems enhance vehicle maneuverability by making wheel rotation less of a chore. This is of utmost significance while maneuvering a vehicle in confined spaces.

Figure 4 1929 Ford model A

- Reducing driver fatigue: Without power steering, drivers would need to apply significant force to the steering wheel, which could lead to fatigue over long periods of driving. Power steering reduces this effort, making driving more comfortable and less tiring.

Figure 5 2022 Toyota Tacoma

- Enhancing safety: Power steering systems can enhance vehicle safety by providing better control in emergency situations, such as sudden swerves or evasive maneuvers.
- Increasing fuel efficiency: Power steering systems use less energy than manual steering systems, which can result in improved fuel efficiency.
- Facilitating customization: Power steering systems can be customized to meet the specific needs of different drivers. For example, the system can be adjusted to provide more or less assistance depending on the driver's preferences or the driving conditions.

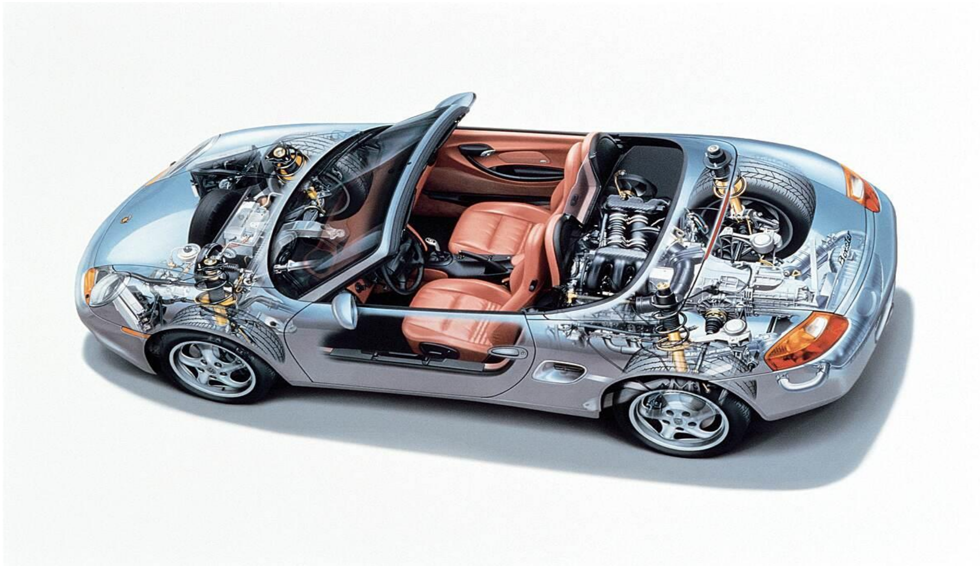

Figure 6 Inner view of mechanism of Car

When it comes to the convenience, security, and efficiency of today's automobiles, power steering is hard to beat. Vehicles such as cars and trucks typically use a rack and pinion steering arrangement. Some classic and modern uses of rack and pinion steering are as follows:

- The rack and pinion steering system of the 1929 Ford Model A was a big improvement over the worm and sector arrangement in the earlier Model T. The improved handling and responsiveness afforded by rack and pinion steering contributed to the Model A's widespread acclaim.
- The rack and pinion steering system combined with the electric power steering in the 2021 Honda Civic Type R ensures accurate and quick handling. The system's goal is to reduce the amount of work required to spin the wheel while still providing useful input to the driver.
- "Power-assisted rack and pinion steering" or "servotronic" steering was first seen on the 1997 Porsche Boxster. This method employs an electric motor to help the driver move the wheel, enhancing control and feedback, especially at high speeds.
- As part of its performance enhancements, the 1966 Shelby GT350—a famous American muscle car—used a rack and pinion steering system. In order to enhance the vehicle's handling and reactivity, the system was developed to allow for more direct and precise steering.
- The rack and pinion steering system with hydraulic power steering is standard on the 2022 Toyota Tacoma, a popular pickup vehicle. The system is built to deliver a smooth and pleasant ride on regular roads and exceptional mobility and control in off-road conditions.

Manufacturers, locations, and descriptions of power steering systems produced in India are included below.

- One such company is Mando Automotive India, with headquarters in Chennai. Vehicles like automobiles, SUVs, and light trucks all benefit from their hydraulic power steering systems, which they manufacture.
- The second is the Gurgaon, Haryana-based JTEKT Sona Automotive India Limited. For automobiles, trucks, and tractors, they produce hydraulic power steering systems.
- Tiruchirappalli, Tamil Nadu is home to Rane TRW Steering Systems Private Limited, the third member of the Rane family. For automobiles like sedans and SUVs, they manufacture electric power steering systems.
- Nexteer Automotive India Private Limited is based out of Pune, Maharashtra, at number four on the list. Producing electric power steering systems for cars, SUVs, and light trucks.
- Bengaluru, Karnataka is home to Bosch Limited, number five on our list. They make hydraulic power steering systems for trucks and tractors in addition to electric systems for passenger cars and commercial vehicles.

Six, along producing brakes, suspension systems, and engine parts, these businesses also produce other auto parts.

Materials

Steel, aluminium, and plastic are all viable options for the construction of power steering systems. The difference between the electric and hydraulic power steering systems is the mechanism used to generate pressure in the power steering fluid.

Performance of Components of power steering

A power steering system's efficiency is directly related on the quality of its individual parts. Some of the most important parts, along with some notes on how well they perform:

The hydraulic pressure used to help the driver turn the steering wheel is created by the power steering pump. The steering system's performance can be evaluated by the pump's ability to provide enough flow and pressure to function smoothly and quietly.

Steering rack or gearbox receive pressure from the pump via the power steering fluid, which works as a hydraulic medium. The performance of the fluid is crucial to the overall efficiency and durability of the system; thus, it must be able to endure high temperatures, prevent foaming, and provide consistent performance throughout a wide variety of operating circumstances.

The rack and pinion or steering gearbox convert the hydraulic pressure from the power steering pump into the mechanical motion needed to turn the wheels. The precision, durability, and resistance to wear and tear of these parts are indicators of their performance.

Connecting the power steering pump to the steering gearbox or rack and pinion requires a set of hoses and lines that can handle high pressures, resist corrosion and wear, and remain flexible over a wide temperature range.

The overall efficiency and dependability of a power steering system depends on the quality of its individual parts. Optimisation of performance and longevity of the system are both aided by routine maintenance such fluid changes and component checks.

Parameters to be considered

When building or assessing the effectiveness of a power steering system, it is important to consider a number of potential points of failure. A few examples are:

If your power steering is making an abnormal amount of noise or vibrating excessively, it could be a sign of old bearings, damaged seals, or improperly balanced components. Excessive noise or vibration can have a negative effect on a system's overall performance as well as the safety and comfort of its occupants.

Possible causes of power steering fluid leaks include faulty hoses, seals, or gaskets. The loss of fluid from these leaks can reduce system efficiency, accelerate component wear, and eventually lead to the failure of the steering pump and other parts.

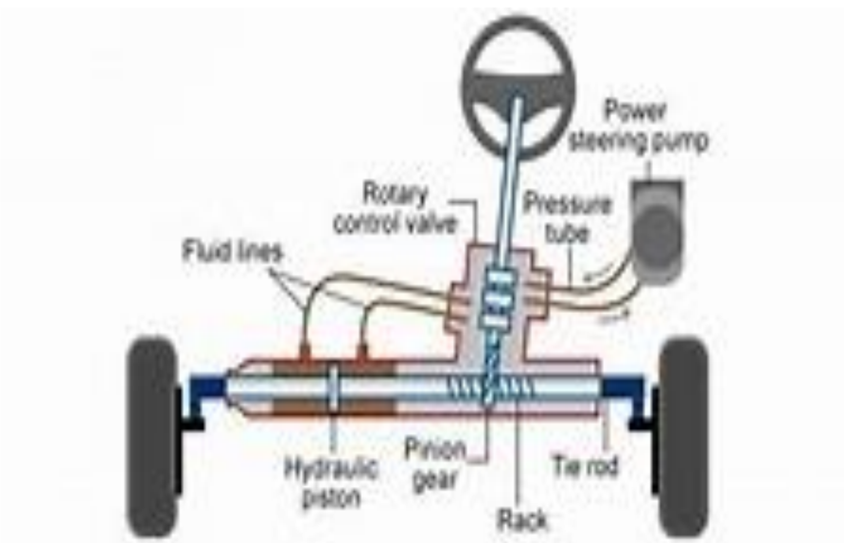

Figure 7 Parameters affecting steering system

If the power steering does not provide the required amount of assistance while turning the wheel, driving the vehicle can be exceedingly tough, if not impossible, especially at low speeds or when manoeuvring in restricted spaces. This is especially true when parking the car.

It can be quite challenging for the driver to keep control of the vehicle if an excessive amount of effort is necessary to move the steering wheel as a result of a defective power steering system. This is especially true when travelling at greater speeds or in an emergency situation.

Overheating can cause damage to the steering pump, hoses, and other components of the power steering system, which can result in a reduction in performance or possibly the complete failure of the system.

Continuous use can eventually cause the components of the rack and pinion steering system to wear down, which can lead to issues such as slack or play in the steering, turning resistance, or even complete breakdown of the system.

Rust and corrosion: The rack and pinion parts are prone to rust and corrosion if they are subjected to wetness and harsh weather for an extended period of time.

The likelihood of the steering system breaking down is increased when there is damage to the rack and pinion, such as cracks or bending in the rack and pinion.

Poor maintenance of the rack and pinion steering system, such as failing to inspect and replace worn components, can be a contributing factor in the eventual failure of the system.

In extremely unusual cases, the rack and pinion steering system may fail to function properly due to a defect in the manufacturing process, such as improper assembly or components of poor quality.

It is important to perform routine maintenance and inspections on the rack and pinion steering system of the vehicle in order to prevent malfunctions and maintain safe driving conditions.

Whenever a power steering system is being developed or reviewed, these failure criteria should be taken into consideration so that the system can achieve its maximum potential in terms of both performance and safety. Problems can be identified and resolved before they become more severe if routine tests and maintenance are performed.

Scope of Study

A project in machine design that involves the construction of a power steering system should provide a system that is secure, dependable, and effective; one that minimises expense and complexity while yet supplying the driver with precise and responsive steering assistance. The goal of the project ought to be to improve the quality of the driving experience without compromising on safety, and it ought to take into account various external circumstances.

During the course of this project, we are going to work on designing and perfecting a power steering system so that it can offer reliable steering assistance to drivers. We will keep a number of considerations in mind when we develop and test the various components of the system, such as the steering mechanism, the electric motor, the sensors, and the control unit. These considerations will include environmental considerations, cost considerations, and performance considerations. In addition, we are going to investigate many different materials and technologies to see whether any of them have the potential to improve the system's performance or extend its lifespan. The objective is to design a high-performance power steering system that is not only easy to produce and maintain but also improves the standard driver's ability to have a pleasant and satisfying time behind the wheel.

Working principle of rack and pinion steering:

The wheel is connected to a pinion that is located on the rack-and-pinion steering box. This pinion is designed to mesh with a rack that is connected to the control rods that are found in the steering system. Both the pinion and the rack have helical gear teeth in their respective components. When helical gearing is utilized, the vehicle functions in a manner that is both quieter and smoother.

When the driver turns the wheel, the pinion rotates, and the rack moves laterally as a result of the driver's action. The tie-rods are attached to the rack by means of ball joints, which also provide movement of the rack and pinion steering mechanism and the suspension. A mechanical advantage can be derived from the reduction ratio. Depending on the diameter of the pinion, the significance of this fraction shifts.

Light steering can be accomplished with a small pinion, but in order to do so, the wheel needs to be spun a great number of times. A larger pinion decreases the number of times the steering column needs to be moved, but as a result, it adds more weight to the steering wheel. The rack in a rack-and-pinion system that's utilized for power steering is built in a somewhat different way than the rest of the system.

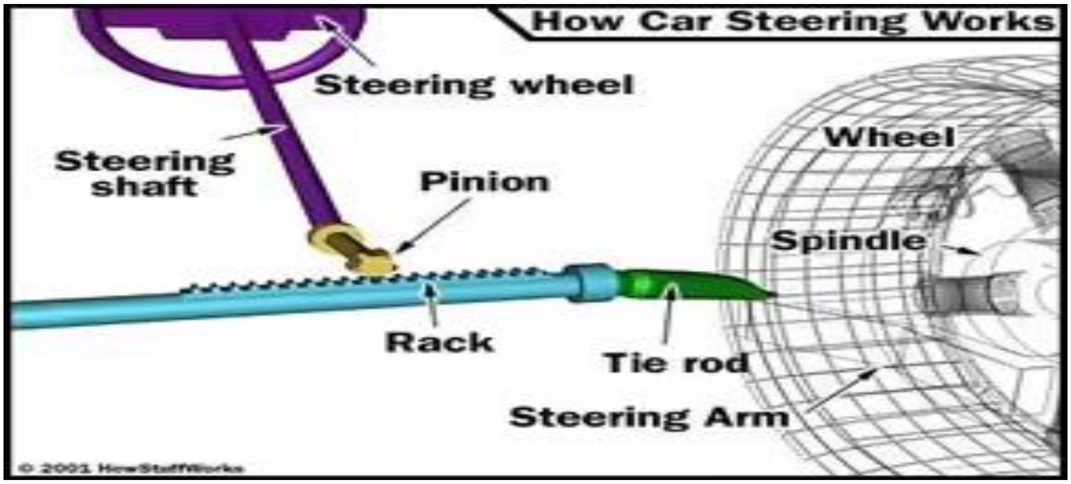

Figure 8 Working of steering system

Cost

There are several potential locations where a leak could occur. There are a few components that could be responsible for the leak. These components include the pump, the reservoir tank, the high-pressure hose, and the return hose.

You have the option of getting under the vehicle yourself and looking for the source of the leak, or you may pay a mechanic to do it for you. The following is an estimate of the costs associated with repairing or replacing the broken component of your power steering system.

The Fees Involved in Making Repairs to the Power Steering Pump

To repair a power steering pump typically requires an investment of between $200 and $350. The cost of a brand-new power steering pump can range anywhere from $400 to $800 (depending on the make and model of your car as well as the auto repair shop that you go with). The cost of replacing the fluid reservoir for the power steering

A common location for leaks in power steering reservoir tanks is the cap and hose connector. However, the filter on the reservoir tank may become clogged, which would result in leaks or noise, particularly when the tank was rotated. The cost to replace the power steering reservoir tank ranges from an average of $150 to $250, but might be higher or lower depending on the type of vehicle and how difficult it is to access the reservoir. The Cost of Purchasing a Brand-New Power Steering Hose

Power steering hoses, which carry power steering fluid from the reservoir to the rack and pinion, are often made of rubber because rubber is the most durable material available. Unfortunately, these rubber hoses will eventually develop fractures, which will cause fluid to flow out of them.

As a result of the crack, either the power steering high pressure hose or the power steering return hose will have to be changed in order to bring the repair to a successful conclusion. It is likely going to cost you anything from $100 to $300 for the parts to replace the hoses on your vehicle with new ones, but the price will vary depending on the make and model of your vehicle. The cost of the labour performed by the replacement will range between $80 and $160.

The price of labour is directly related to the hourly rate charged by the technician. Changing the hoses for power steering normally costs between $80 and $120 an hour, though this number can vary depending on the mechanic. As a direct consequence of this, you may anticipate the cost of its replacement to range anywhere from $180 to $460.

Figuring Out How Much a Brand-New Power Steering Hose Will Cost

If you need a quick patch while you're away from home or if the line is too small to replace, a do-it-yourself hose repair is a wonderful alternative for you to consider. Find a local auto supply shop that sells male-to-male brass couplers, along with two hose clamps and a tool for cutting the hose, and make your purchase there.

It is necessary to locate the section of the hose that is leaking and then cut it. After severing the broken hose, insert the coupler into each of the remaining hoses, and then tighten the hose clamps on both ends. This simple repair shouldn't set you back more than ten dollars and should get you back on the road in no time. Due to the fact that the state of the hose has deteriorated to the point where it is likely to develop additional leaks, you will eventually need to replace the hose in its entirety.

How Much Does It Cost to Replace the Power Steering Rack and Pinion?

Fixing a leak in a rack and pinion system will normally run between $500 and $1,200, depending on the severity of the problem. The price is substantially higher than that of other components of the power steering system as a result of the necessity of performing a comprehensive overhaul on the steering rack and pinion. This includes replacing all oil seals and O rings on the steering rack as well as performing a front wheel alignment on the vehicle.

If you take our recommendations into consideration, you won't have to worry about the power steering system springing any leaks. Because doing so places a significant amount of strain on the system, one easy thing you can do is to make sure that you do not keep the steering wheel in a totally rotated position for more than ten seconds at a time.

For your convenience, the following is a rundown of the typical costs connected with repairing or replacing the various components of your power steering system:

The following is a rough estimate of the cost to repair a broken pump that controls the power steering: $200 to $350

Changing the pump that regulates the power steering will cost between $600 and $1200.The cost of changing the power steering reservoir is between $150 and $250.Power steering hose replacement, ten bucks The cost of replacing the power steering hose ranges from $180 to $460Power steering rack and pinion alignment can be fixed for between $500 and $1,000.

Indian Standards

There are several Indian standards that can be used to design steering systems. Here are some examples:

- IS 4460: This standard specifies the requirements for straight and helical teeth rack and pinions for general engineering purposes.
- IS 5239: This standard specifies the requirements for rack and pinion steering gears for automotive vehicles.
- IS 11487: This standard specifies the requirements for helical teeth rack and pinions for use in machine tools.

Advantages of Electronic Power steering

Electronic power steering is one of those products that exemplifies the advantages that come with being a product of the modern day.

- The electric power steering offers an experience that is both more responsive and more precise.
- The previous power steering system was less efficient than this one, which is due to the fact that this one does not require the usage of a working fluid.
- The form factor of the EPS assembly is lowered since the constituent pieces that make up the assembly are lightweight and compact in size.
- This also contributes to the ability of the autos to transition between a varieties of different driving modes. Simply pressing a button allows the driver to make adjustments to both the responsiveness of the steering wheel and the quantity of input it gives. As a result of this, it can be modified.
- Because the engine isn't responsible for providing power to the pump, it is more effective and gives the impression of having more force. (There is less of a loss of energy)
- Front-engine, front-wheel-drive cars are the norm because of their compact size and low steering-elasticity requirements. Internal damping is maintained Front-engine, front-wheel-drive vehicles are the usual because of their compact size.
- It is not necessary to have the intermediate rod or the idler arm.
- The rack-and-pinion steering gearbox is advantageous in that it is uncomplicated, straightforward, and easy to construct. It is also relatively inexpensive.

- It's not hard to achieve accurate operation.

Scope of Optimization

The optimal performance of a rack and pinion steering system can be influenced by a number of factors, including the following: Optimisation of the geometric design involves finding the size and shape of the rack and pinion components that will result in the least amount of play or backlash, the smoothest steering, and the necessary amount of steering angle.

Material optimisation: The performance of a rack and pinion system can be significantly impacted by the selection of materials and the properties those materials possess. It is feasible to optimise the use of materials to achieve decreased weight while simultaneously increasing the strength, durability, and wear resistance of the finished product.

Lubricant and friction optimisation: Rack and pinion systems gain a significant amount of advantage from reduced friction and wear as a result of using the appropriate lubricant. Components of lubrication optimisation include making sure the appropriate lubricant is used, doing so in the correct manner, and staying on top of any necessary maintenance.

It is possible to improve the quality of rack and pinion systems by optimising the production process, which will also help to raise precision and reduce costs.

A vehicle's control system, which includes the rack and pinion steering, can be fine-tuned to produce optimal handling, stability, and safety for the vehicle. This can be accomplished by using the vehicle. The utilisation of sensors, software, and hardware for control can allow for improvements to be made in terms of the responsiveness, stability, and performance of the steering.

Power steering systems can have their weight reduced by using materials that are lighter in composition and by reducing the number of components that are required for their operation. This has the ability to improve fuel economy while also enhancing performance in various bends.

It is beneficial for both the driver's experience and the longevity of the components of the power steering system when noise and vibration are reduced as a result of proper tuning of the system. Optimisation of the control algorithms used in active steering control systems, as well as the use of better materials and design techniques to reduce friction, both contribute to this goal. Optimisation of the reliability of power steering systems can be accomplished by employing materials with a longer lifespan and refining the design of the system to reduce wear on components. The longevity of the system and the expenses of its maintenance may both benefit from this.

It is possible to make power steering systems safer by improving the algorithms that are utilised by active steering control systems. As a result, their performance can be improved when subjected to demanding conditions. If you use cutting-edge diagnostic technology to locate and repair power steering issues in your car before they become more severe, you can improve the overall safety of your vehicle.

When it comes to optimising rack and pinion steering systems, expertise in mechanical design, the science of materials, manufacturing, and control systems are all required components.

New advance Research in power steering

Active steering control systems are installed in modern automobiles. These systems make use of sensors and advanced control algorithms in order to adapt the steering reaction to many elements such as the speed of the vehicle, the conditions of the road, and the inputs provided by the driver. These devices can improve the control and stability of a vehicle, and they are especially helpful at high speeds and in emergency situations.

Energy Recovery Systems: When the vehicle is slowing down, the energy that is normally lost from the steering system can be reclaimed by energy recovery systems and put to use to either charge the battery or power the electric motor. These modifications have the potential to improve fuel efficiency while also lowering pollutant levels.

In order to avoid costly failures and downtime, modern vehicles are equipped with features such as "smart diagnostics," which utilise sensors and algorithms to detect and diagnose faults with the power steering system. This helps drivers avoid costly breakdowns and downtime.

Sustainability and consideration for the environment are two issues that are receiving increased attention from automobile manufacturers. In today's power steering systems, both energy-efficient components and systems, as well as environmentally friendly raw materials, are being incorporated into the design process.

Chapter3: Mathematical model

When it comes to the design and analysis of electric power steering systems, modelling is an extremely important part of the process. Constructing a mathematical model of the steering system's constituent pieces is necessary in order to build a computer simulation of the reaction of the system under changing loads and circumstances. Modelling is used to improve the design of the steering system so that it is both as effective and as safe as possible.

To begin, there are physical models, which require the creation of a physical representation of the control system (either a scale model or a prototype). These models can be scaled up or down depending on the complexity of the system. These models can be placed through a number of different stress tests in order to assess how they operate and identify any potential design defects that may exist.

Analytical models characterize the behavior of the steering's components by use mathematical equations as a means of representation. Through the utilization of these models, it is possible to make predictions regarding the stresses, strains, and deformations that the components will experience under a variety of loading conditions.

Computer models, in third place: A digital illustration of the steering's components is crafted through the use of computer-aided design (CAD) software. These models can be used to reproduce the behavior of the components under a variety of loads and conditions, which enables one to conduct a more in-depth analysis of the steering system's performance.

Ackerman's Angle

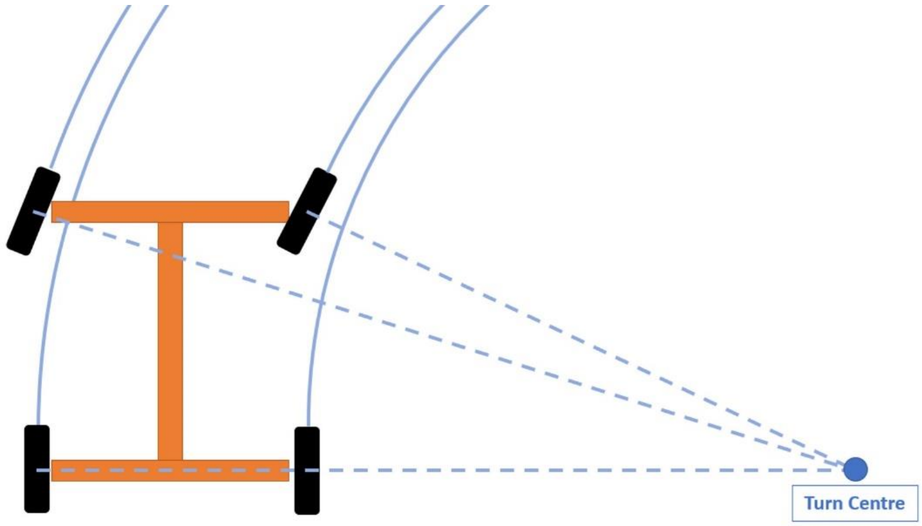

Figure 9 Ackerman's Angle

The different curvature radii mean that to avoid sliding, the steering geometry must steer the inside front tyre at a larger angle than the outside front. Ackermann Steering refers to the geometric configuration that allows both front wheels to be steered at the appropriate angle to avoid tyre sliding.

For a given turn radius R, wheelbase L, and track width T, engineers calculate the required front steering angles (δ_(fin) and δ_(fout)) with the following expressions:

$$\delta_{f,in} = \tan^{-1}\left(\frac{L}{R - \frac{T}{2}}\right) \quad \delta_{f,out} = \tan^{-1}\left(\frac{L}{R + \frac{T}{2}}\right)$$

The difference in front-wheel steer angle as a function of the input steer angle is known as Dynamic Toe. If the vehicle dimensions are known, it is possible to construct a curve of the desired to change for the full range of expected turn radii, such as the example.

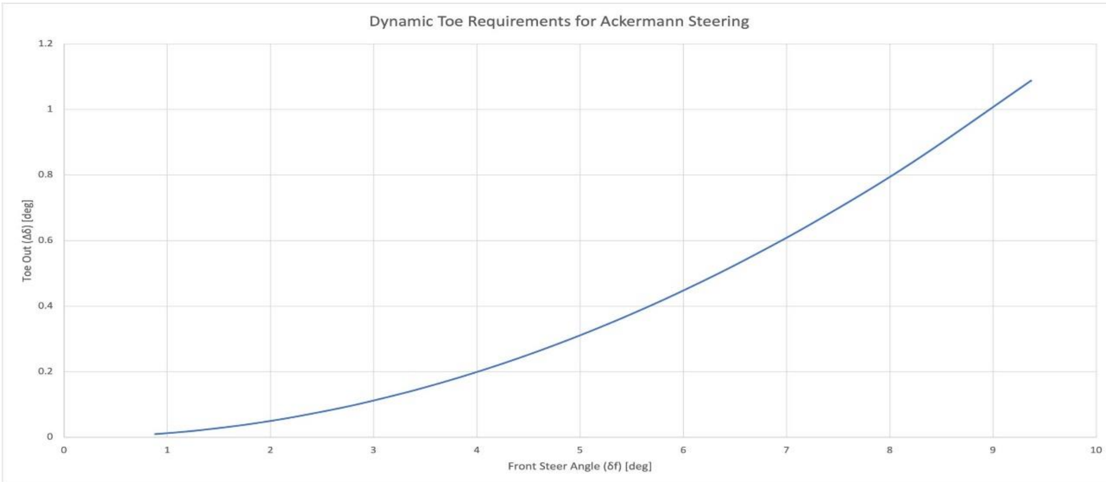

Figure 10 Ackermann Steering configuration for a sample vehicle

The tighter the desired vehicle turn radius, the larger the difference in steer angles required. Ackermann Steering geometry is a practical measure to avoid sliding tyre while in the pit lane or parking on the street. The picture gets much more complicated once the vehicle is at speed.

Incorporating Slip Angles

A vehicle navigating a curved path at speed requires centripetal force provided by the tyre lateral force capacity to maintain its trajectory. The centripetal force occurs when the tyre assumes a slip angle. The subsequent difference between the tyre heading and the contact patch's orientation shifts the turn center of the vehicle forward, as depicted.

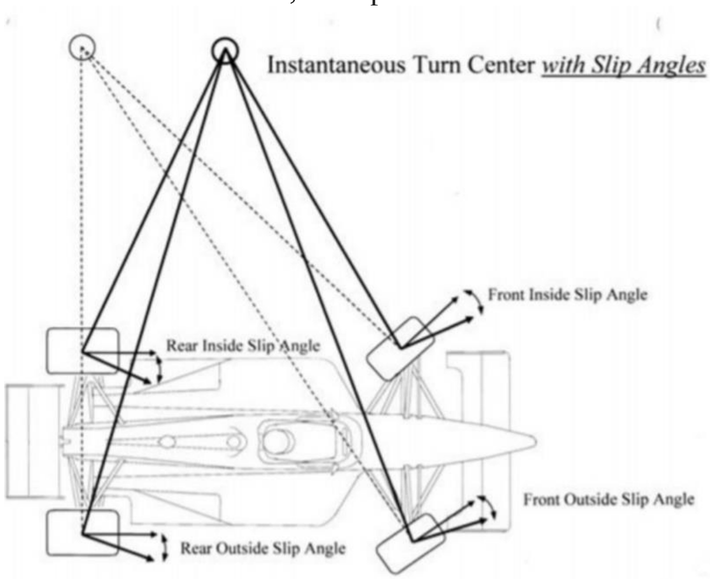

Figure 11 Effect of tyre slip angle on vehicle turn centre

If a tyre has a slip angle, the lateral sliding velocity component present is greater than zero.

For this reason, the goal is to fine-tune the sliding conditions of each tyre to optimize total performance, rather than try to avoid tyre slip entirely. The key to unlocking this performance comes from understanding the relationship between vertical load and lateral force capacity in tyres.

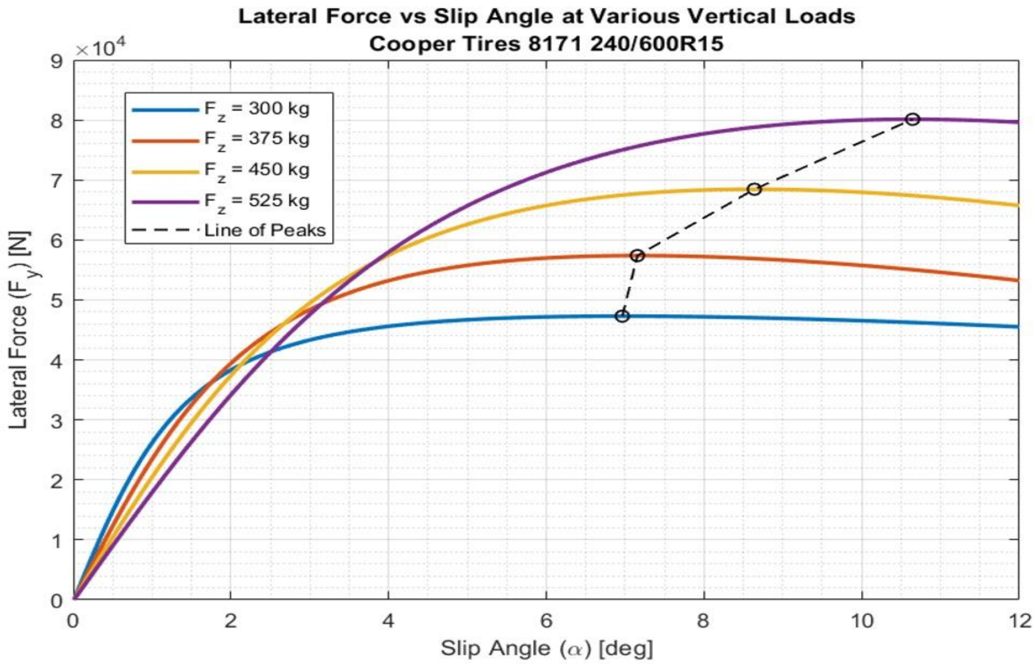

Figure 12 Lateral force vs slip angle curves for a Cooper Tires Indy Lights 2017 Front Tyre

The higher the vertical load on the tyre, the greater peak lateral force it can produce. At higher vertical loads, the peak lateral force arrives at a higher slip angle. This trend is expected but not necessarily present in all tyre and may depend on compound or construction.

The relationship between vertical load and peak slip angle is known as the Line of Peaks. Characterizing the Line of Peaks is essential due to the onset of lateral load transfer during a cornering maneuver, transferring vertical load from the inside tyre to the outside tyre.

It is critical to make sure both tyres operate at their peak slip angles simultaneously to maximize performance. In the case of the Indy Lights tyre, this means that the more heavily loaded outside tyre should be at a higher slip angle than the inside tyre. Steering the outside tyre more than the inside for a given steering wheel input achieves this.

The result is the exact opposite of Ackermann Steering and is known as reverse Ackermann or anti-Ackermann. Many race cars fitted with Anti-Ackermann exploit the peak operating conditions of the individual tyre.

Designing for Ackermann Mechanism

When the difference in the steering angles of the inside and outside tyre is equal to the geometric center of the turn at low speed, we say that the vehicle's steering geometry is at 100% Ackermann. The majority of racing vehicles adopt a hybrid strategy, which involves running a little bit of both.

Instead, in order to accomplish their design goals and work as they had envisioned it, they decided to strike a balance between these two extremes and establish a happy medium.

When it comes to the design of a race car, one of the most crucial aspects to take into consideration is the steering geometry. It is necessary for the designers of a racing car to be familiar with both the maximum speed and the layout of the course.

As the track speed and radius decrease, it becomes increasingly vital to have Ackermann's aid when negotiating hairpins and other tight turns, which are areas of the track where geometry takes precedence.

The designers need to be able to forecast the vertical loads that will be placed on each tyre by considering the specifications of the vehicle and the track. The level of difficulty of the research will be directly proportional to the amount of data that is available; nonetheless, there are a few key criteria that include mass, ride height, lateral load transfer distribution, and downforce.

The information obtained from the analysis of tyre data that was used to create the Line of Peaks and an approximation of the vertical loads that were present at each turn can throw light on the peak slip angles that were experienced by the two front tyres at each turn when taken together. With the help of these numbers, designers are able to produce a dynamic toe curve that is comparable to the one shown in Figure 2.

Because of packaging and kinematic constraints, it may not be possible in many situations to design a steering geometry that can match the intended curve for all of the track's turns. The designer will need to make a decision regarding the level of performance that must be conceded.
Lastly, it is essential to remember that Ackermann is not the only way to adjust individual tyre slip angles. Bump steer can be incorporated kinematically to cause additional steer angle from suspension travel, which engineers can exploit when a vehicle rolls into a corner.
Also, no suspension components are purely rigid, and compliance in the links can affect the tiers' steered angle in a corner. Suppose these factors are well understood and integrated into the suspension system.
In that case, it can help eliminate the compromises discussed above, but if they are ignored or misunderstood, it can lead to unpredictable cornering behavior and performance losses.

Design of Boost Curve:

The power-assisted characteristic of EPS has curves of sorts. Among the three kinds of power-assisted characteristic curves, the straight-line boost curve is the most widely used one. The assist torque is proportional to the torque of steering wheel. Thus, road feel intensity is a constant, which is convenient to design and adjust the control system easily. The assist torque for straight line type is calculated as follow

$$T_m = \begin{cases} 0 & 0 \le T_d < T_{d0} \\ K_V(V)\cdot(T_d - T_{d0}) & T_{d0} \le T_d < T_{d\max} \\ T_{\max} & T_d \ge T_{d\max} \end{cases}$$

; where Tm is assisting torque, Td is steering wheel torque, Td0 is steering wheel torque when assist torque begin to generate, Tdmax is the steering wheel torque when maximum assist torque is applied, KV(V) is assist coefficient, Tmax is the maximum torque for steering wheel. Td0 and Tdmax are related to the feeling of driver. Thus, their values can be obtained by experiment, on the basis of steering portability and road feel. The assist torque generated for cars when Td0=1.0N.m, while the maximum assist torque Tdmax is 7.0N.m. Based on the model established, the maximum torque for steering wheel was gained through simulation.

Assist Torque when velocity is 0km/h

The maximum assist torque can be calculated by

$$T_{m0} = T_{r\max 0} - T_{d\max}$$

$$T_{r\max 0} = \frac{\frac{\mu}{3}\sqrt{\frac{G_1^3}{P}}}{i \cdot \eta}$$

; η is the efficiency of steering gear

mu is coefficient of sliding friction

G1 is load for the front axle

P is tiring pressure

i is steering gear angle ratio

The torque of steering wheel was recorded by rotating uniformly to one side limit position, under the velocity of 20km/h, 40km/h, 60km/h, 80km/h and 100km/h. The maximum value for each velocity represented its Tmax, shown in Table 1. The assist torque range is 1.0 N.m to 7.0 N.m.

Therefore, the assist torque in this range can be obtained by using interpolation methods. The assist torque can be calculated by Eq.

$$T_m = \frac{(T_d - T_{d0})(T_{max} - T_{d\,max})}{T_{d\,max} - T_{d0}}$$

Taking all these values into the above equations, the assist coefficient KV(V) was calculated under different velocities, shown in Table 1.

Velocity	0 [km/h]	20 [km/h]	40 [km/h]	60 [km/h]	80 [km/h]	100 [km/h]
Tmax	28.1	20.3	16.7	11.4	8.9	5.3
Kv (V)	3.52	2.23	1.62	0.73	0.32	-

Table1 Lateral force vs slip angle curves for a Cooper Tires Indy Lights 2017 Front Tyre

Along with increase in velocity, the value of assist coefficient was reduced. When velocity was 100 km/h, Tmax<Tdmax, there was no need for assist torque.

Boosting Curve

By using polynomial regression, the assist coefficient was obtained.

$$K_V(V) = 3.4754 - 0.0606v + 0.0003v^2 \qquad (R^2=0.9928)$$

Therefore, the straight line boost curve can be established, shown in Fig.5.

$$T_m = \begin{cases} 0 & 0 \le T_d < T_{d0} \\ (3.4754 - 0.0606v + 0.0003v^2)\cdot(T_d - 1) & T_{d0} \le T_d < T_{d\,max} \\ T_{max} & T_d \ge T_{d\,max} \end{cases} \qquad (6)$$

Fig.3 showed the assist force curve in different velocities.

Based on the designed straight line boosting curve, simulation experiment was done to illustrate its effect on assist characteristics. Angle step function response experiment was done in ADAMS software. The initial velocity was 80 km/h. The input is 100-degree angle step, which imitated the angle input of steering wheel, shown in Fig.4. Output was the angular velocity of the whole vehicle, which can show the stability of vehicle. Simulation result with and without EPS were shown in Fig.5. As time went by, angular velocity for the curve without EPS system was obviously higher than that with EPS system using the straight-line boosting curve. Both reacting time and overshoot value reduced when using straight line boost curve EPS system, which can ensure the dynamic reaction and stability when car was moving.

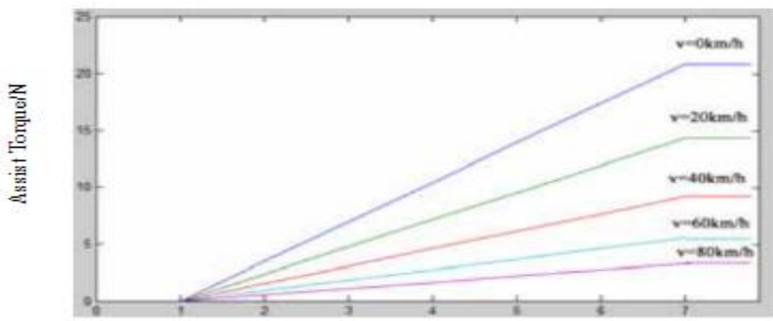

Figure 13 Straight line boost curve under different velocities

On the basis of whole-vehicle model, the straight-line type boost curve was designed and evaluated in a whole vehicle model condition. Simulation showed that the designed boost curve reduced reacting time and overshoot value, thus ensure the dynamic reaction and stability when car was moving. Further research is under way on application of electronic control with the aim of further improving functions and performance.

Chapter4: Modelling and coding

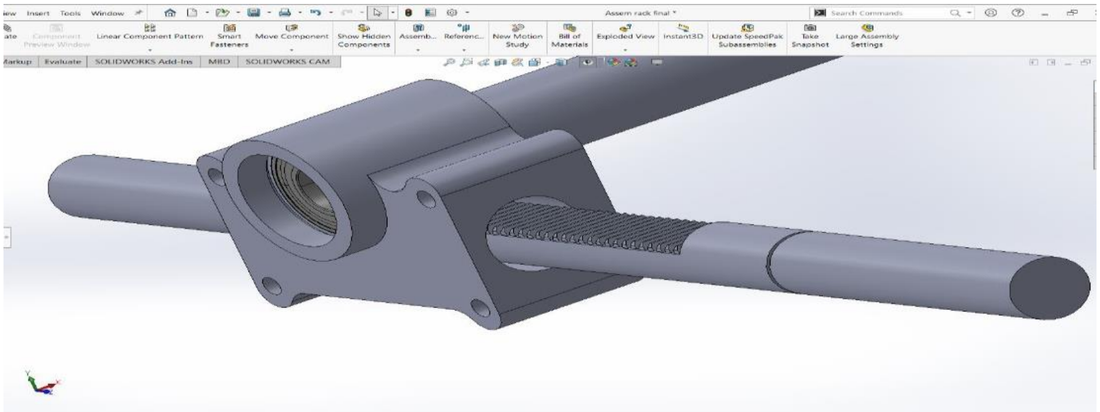

Figure 14 Design of steering system

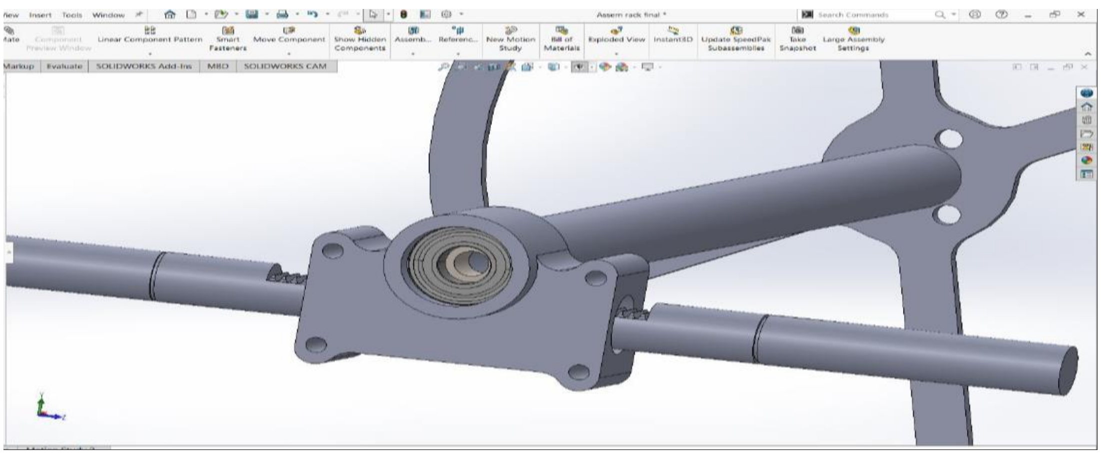

Figure 15 Closeup view of the rack and pinion

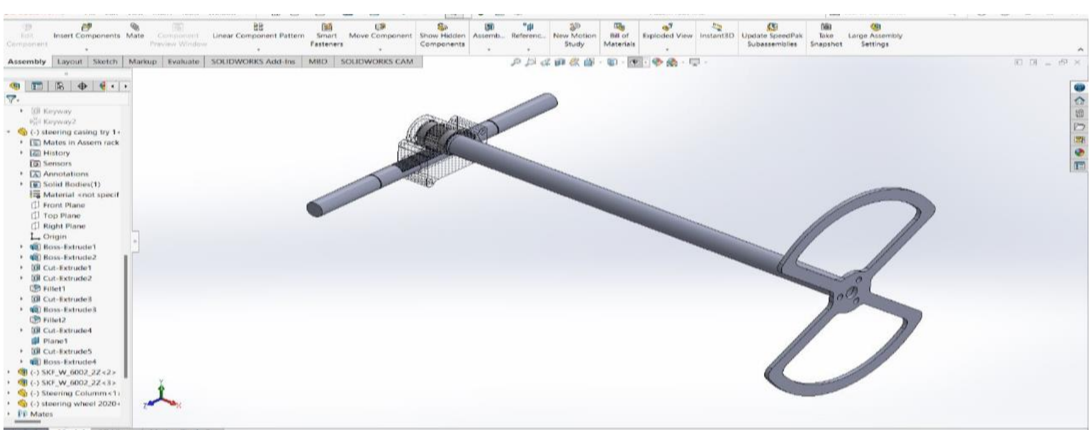

Figure 16 Rack and Pinion in steering system

Modelling the power steering in CAD (Computer-Aided Design) software is a crucial part of the design process. SolidWorks is widely used in the engineering industry as a tool for 3D modelling and simulation. Key features of a power steering CAD model in SolidWorks include the following:

Incorporating a New Component: Select "New" from the file menu, and then "Part" to make a new part in SolidWorks. You'll be able to access the part file and begin making the various steering parts.

The first thing to do while making a new piece is to sketch out its general outline. Lines, arcs, circles, and rectangles are only some of the drawing tools that can be used for this purpose. A power steering is sketched out in its entirety, from the bottom up. This includes the base, power cylinder, hook, support column, and vertical and top supports.

After the sketch is finished, the following step is to extrude it to make a three-dimensional model. A 2D sketch can be extruded into a 3D object by extending it in a certain direction. To extrude a sketch in SolidWorks, pick the sketch and then go to the Features menu, where you'll find the "Extrude" command.

Once the component's basic shape has been established, it can be refined by adding features. Improving the functionality or visual appeal of a component may need modifying its shape.

Assembly: Once all the components have been made, they must be put together to form the power steering. To accomplish this, a new assembly file is made and the individual components are imported into the file. After everything is in place, the steering may be assembled.

Simulation: Finally, once the steering is assembled, it can be simulated in SolidWorks to test its performance and durability. This is done using the simulation tools in SolidWorks, which allow you to analyse factors such as stress, strain, deformation, and fatigue. The simulation results can then be used to optimize the design and improve the performance of the steering.

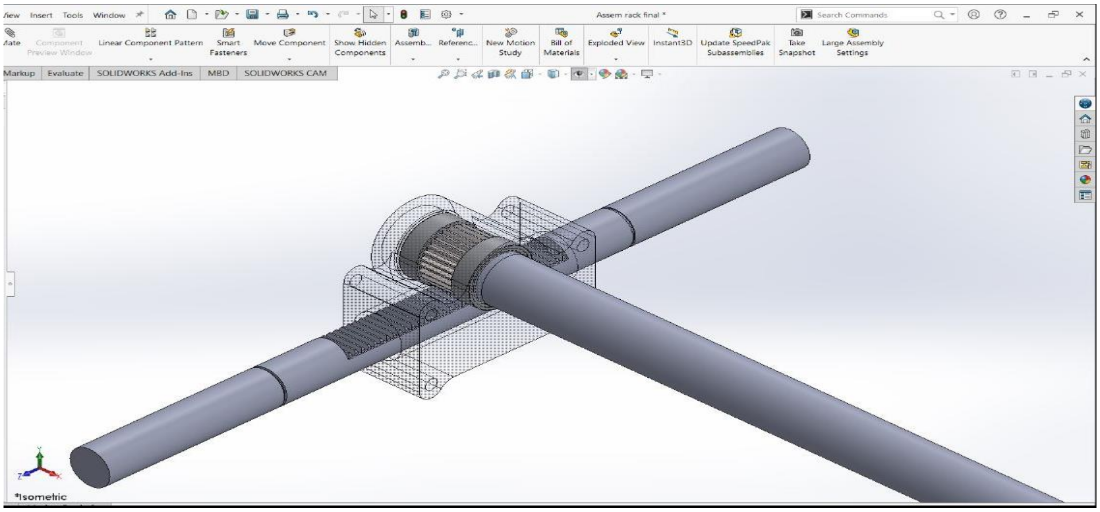

Figure 17 Rack and Pinion with hidden geometry

Coding

- **MATLAB Code for geometry of steering (Calculate Inner and Outer wheel Angle)**

```
% Define the input parameters
L = 1.5; % Distance between the wheels in meters
R = 10; % Turning radius in meters
delta = 0:5:45; % Steering angles in degrees

% Convert the steering angle from degrees to radians
delta_rad = delta*(pi/180); % Ackerman Angle

% Calculate the steering geometry
alpha = atan(L./(R./tan(delta_rad)+L/2));
beta = atan(L./(R./tan(delta_rad)-L/2));

% Convert the steering geometry from radians to degrees
alpha_deg = alpha*(180/pi);
beta_deg = beta*(180/pi);

% Plot the inner vs outer angle graph
plot(delta, alpha_deg, 'r', delta, beta_deg, 'b');
xlabel('Steering angle (degrees)');
ylabel('Wheel angle (degrees)');
legend('Inner wheel', 'Outer wheel');
title('Inner vs Outer Wheel Angles');
```

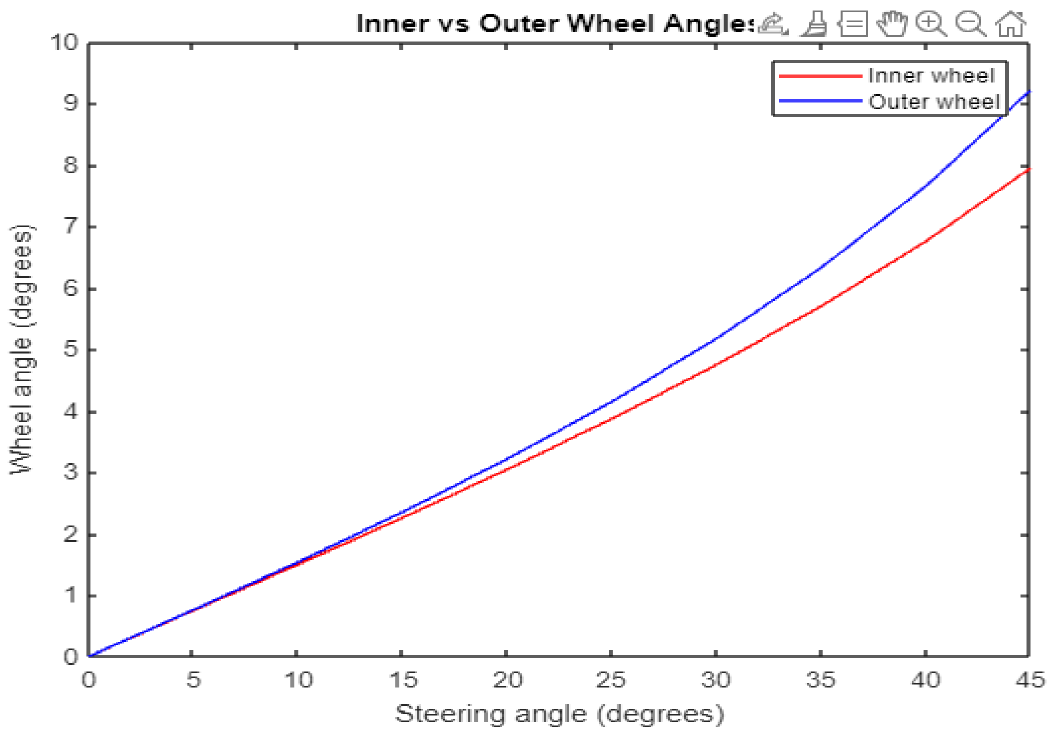

Figure 18 MATLAB Code for geometry of steering

- **Input and Output Torque**

```
clc
clear all
% Define system parameters
L = 1.5; % Length of rack (m)
N = 20; % Number of teeth on pinion
rho = 7850; % Density of steel (kg/m^3)
t = 0.01; % Thickness of rack (m)
h = 0.05; % Height of rack (m)
E = 200e9; % Young's modulus of steel (Pa)
Cf = 0.2; % Friction coefficient
r = 0.2; % Steering wheel radius (m)
omega = 2*pi/3; % Steering wheel angular velocity (rad/s)

% Define input torque range
Tin_range = 0:5:100; % Input torque range from 0 Nm to 100 Nm in increments of
5 Nm

% Compute output torque and other parameters for each input torque value
Tout_range = zeros(size(Tin_range)); % Initialize output torque array
Ts_range = zeros(size(Tin_range)); % Initialize steering torque array
Pa_range = zeros(size(Tin_range)); % Initialize power steering assist array
for i = 1:length(Tin_range)
```

```
    Tin = Tin_range(i);
    dx = Tin * pi * r / N / (rho * t * h * L * E); % Compute rack displacement
    Tout_range(i) = (rho * t * h * L * E * dx^2) / (2 * pi); % Compute output
torque
    Ts_range(i) = Tout_range(i) / (1 - Cf); % Compute steering torque required
    Pa_range(i) = Ts_range(i) * omega; % Compute power steering assist
end

% Display results for a specific input torque value
Tin = 50; % Input torque (Nm)
dx = Tin * pi * r / N / (rho * t * h * L * E); % Compute rack displacement
Tout = (rho * t * h * L * E * dx^2) / (2 * pi); % Compute output torque
Ts = Tout / (1 - Cf); % Compute steering torque required
Pa = Ts * omega; % Compute power steering assist
disp(['Results for input torque of ' num2str(Tin) ' Nm:']);
disp(['Rack displacement: ' num2str(dx) ' m']);
disp(['Output torque: ' num2str(Tout) ' Nm']);
disp(['Steering torque required: ' num2str(Ts) ' Nm']);
disp(['Power steering assist: ' num2str(Pa) ' W']);

% Plot input torque vs output torque
plot(Tin_range, Tout_range, 'LineWidth', 2);
xlabel('Input torque (Nm)');
ylabel('Output torque (Nm)');
title('Input torque vs Output torque');
```

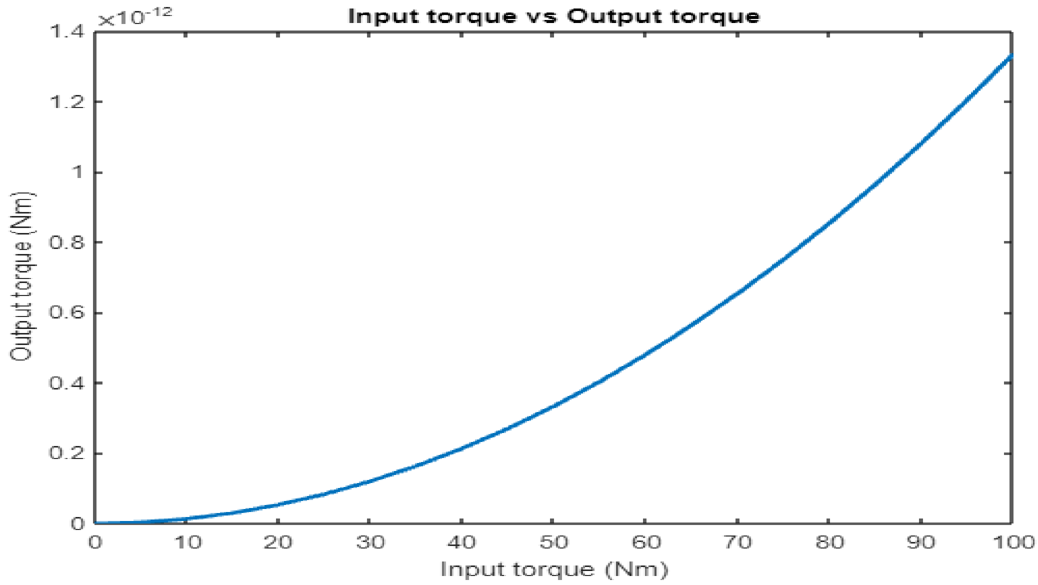

Figure 19 plot for Input and Output Torque

- **Pump Efficiency**

```
clc
clear all
% Define the input parameters
p_in = 100; % Input pressure in bar
p_out = 50; % Output pressure in bar
q = 10; % Flow rate in liters per minute
P = 746; % Power in Watts

% Convert the flow rate from liters per minute to cubic meters per second
q = q/60000;

% Calculate the pump efficiency
efficiency = (p_out*q*1000)/(p_in*P);

% Display the pump efficiency
disp(['The pump efficiency is ',num2str(efficiency*100),'%.']);
```

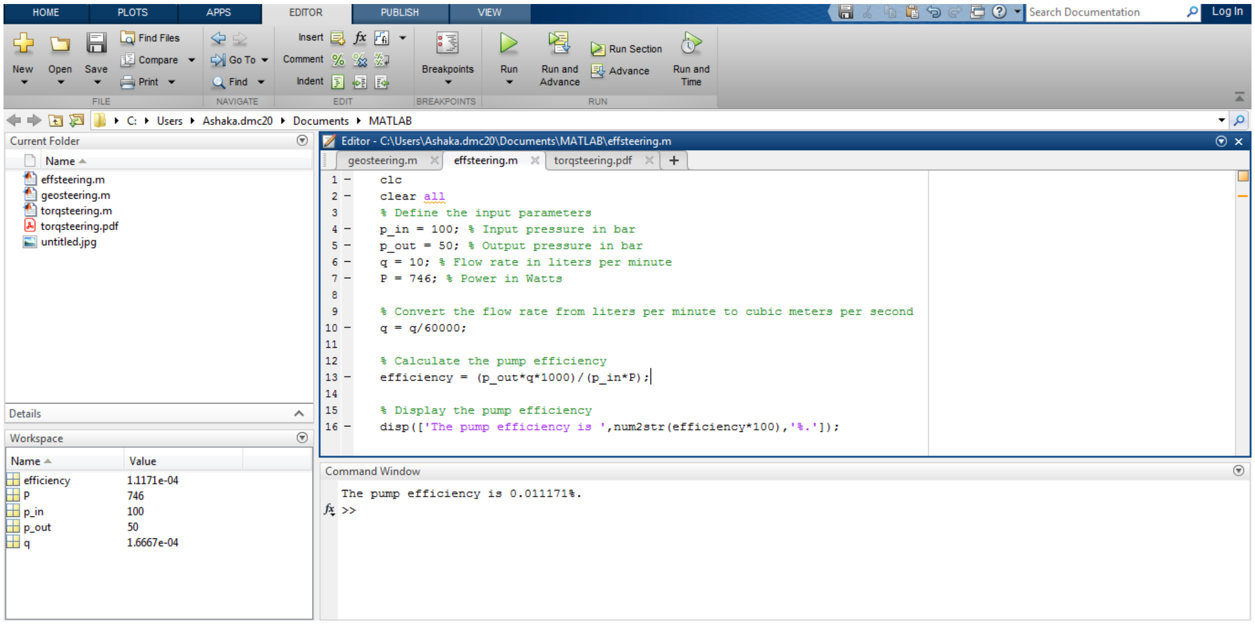

Figure 20 Pump Efficiency

- Steering Pressure

```
clc
clear all
% Define the variables
Q = linspace(0, 10, 100); % flow rate values from 0 to 10
area = linspace(1, 10, 100); % Throttle_area values from 1 to 10

% Calculate pressure for all combinations of Q and Throttle_area
[Q, area] = meshgrid(Q, area);
pressure = 6*(Q.^2)./((100*area).^2);

% Plot the pressure vs area
plot(area, pressure);
xlabel('Throttle Area');
ylabel('Steering Pressure');
title('Steering Pressure vs Throttle Area');
```

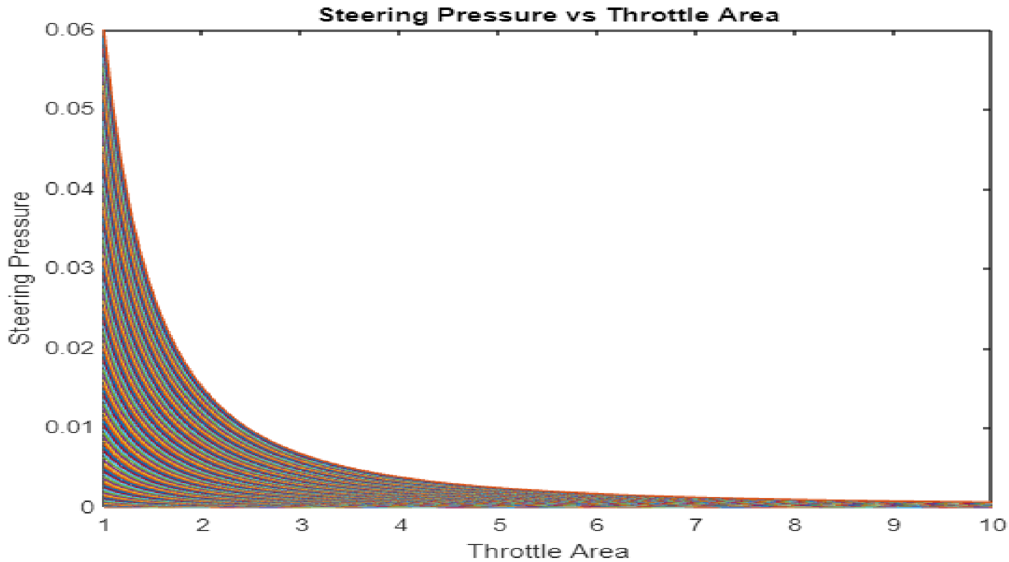

Figure 21 steering pressure vs throttle area

In this code, the flow rate is varied from 0 to 10 in increments of 0.1, and the throttle area is varied from 1 to 10 in increments of 0.1. The variables Q and area are defined using the linspace function, which creates linearly spaced vectors of values.

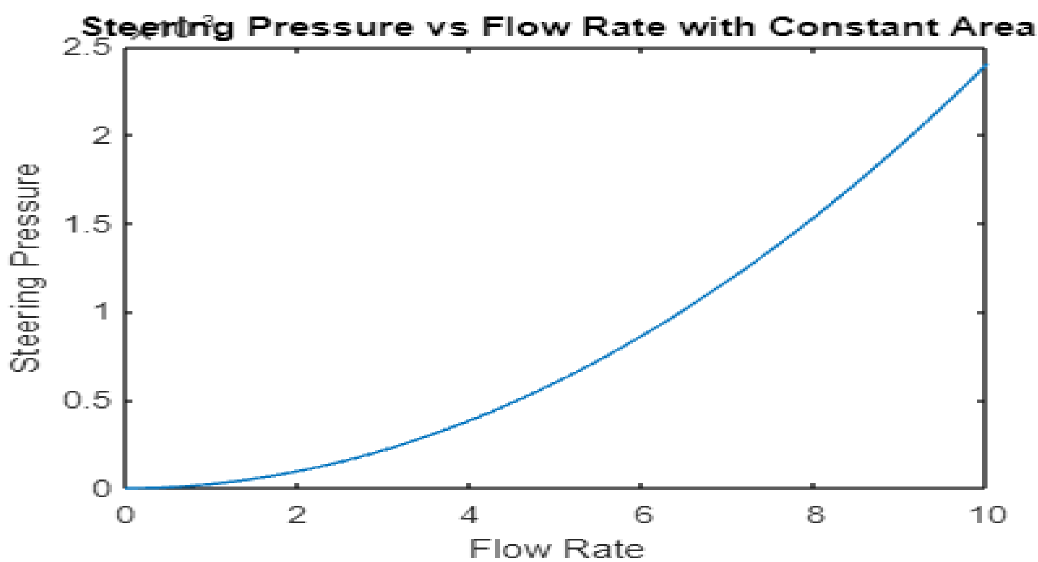

Figure 22 steering pressure vs flow rate with constant area

Chapter 5: Static analysis and results

Through the use of structural analysis during the machine design process, power steering systems can be improved to be more effective and reliable. According to Markets & Markets, the global market for automotive electric power steering will rise at a compound annual growth rate (CAGR) of 5.22% from USD 13.5 billion in 2020 to USD 25.9 billion in 2025. This represents an increase from USD 13.5 billion in 2020. As a direct consequence of this, there is an urgent requirement to enhance both the structural design and operational capabilities of the electric power steering systems found in automobiles.

The kinematics, dynamics, and control systems subfields of study are just a few of the many that are included in the examination of the structure of electric power steering in machine design. Kinematic analysis is a method that evaluates the motion of the steering system and the interaction between its many different parts. This helps to ensure that the steering will be accurate and responsive. The purpose of dynamics analysis is to investigate the pulls, pushes, and twists that are exerted on the steering mechanism, as well as how these factors influence the overall performance of the system.

Programming algorithms that will guide the electric motor and provide assistance to the driver is a necessary part of analyzing control systems. It is possible to obtain optimal performance and responsiveness by monitoring how the system reacts to a variety of inputs and then modifying the control settings in accordance with those measurements.

During the design phase of the machine, it is vital to incorporate a number of different technical aspects into the study of the structure of the electric power steering in order to achieve optimal system performance and dependability. This is a laborious venture that necessitates in-depth understanding of machine design, electrical engineering, and software development in addition to modern simulation tools and modelling strategies. Time is also required to complete this project. However, if we conduct extensive study, we should be able to create a power steering system that not only accomplishes all of these goals, but also enhances the ride quality and reduces emissions.

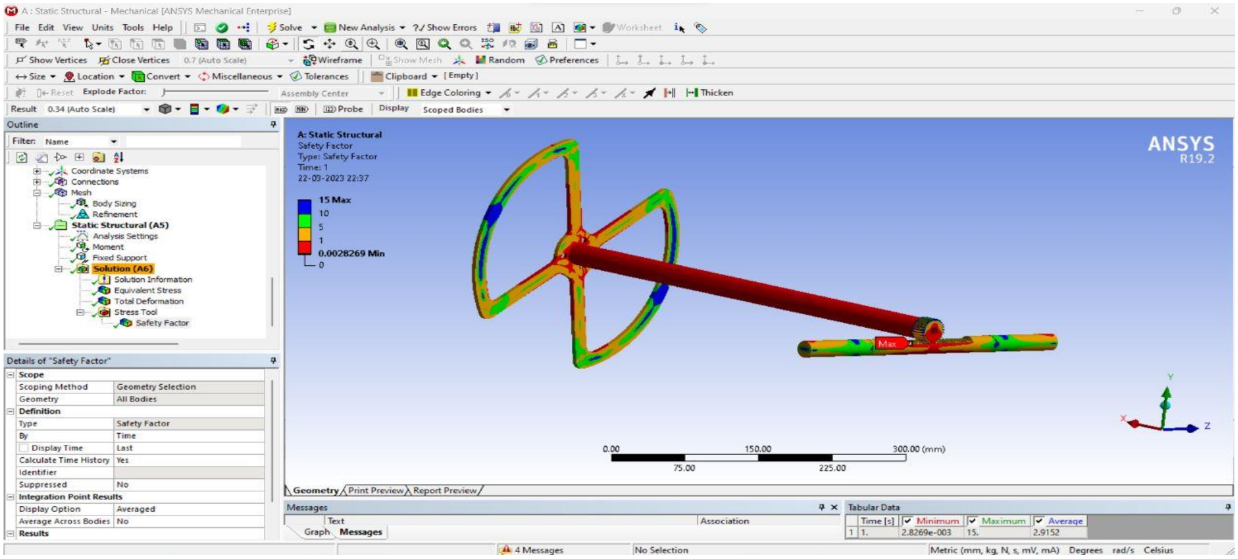

Figure 23 static structural analysis for safety factor

This is the static structural analysis for safety factor of rack and pinion inserted in the power steering wheel where maximum factor of Safety is 15 and minimum is 0.0028.

The component is most likely to fail from the steering side.

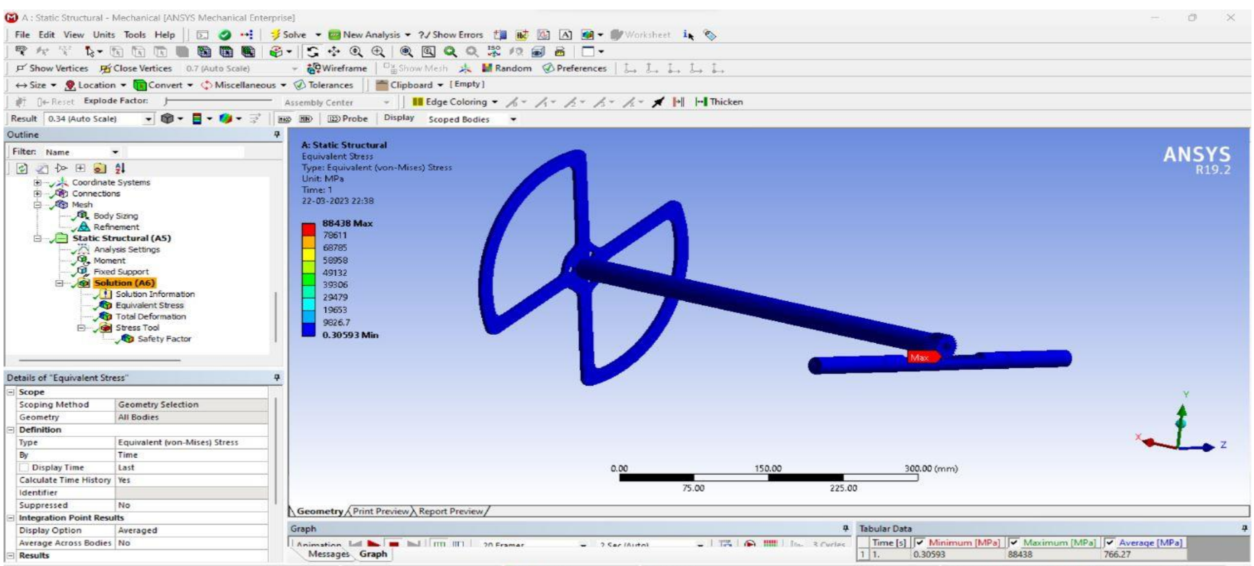

Figure 24 static structural analysis for equivalent stress

This is the static structural analysis for equivalent stress of rack and pinion inserted in the power steering wheel where stress is 0.3053. The power steering rack and pinion assembly has been the subject of a static structural analysis. Deformations range from a maximum of 103.9 to a minimum of 0.0.The side of the component that is closest to the steering wheel is more likely to become distorted due to its lower factor of safety.

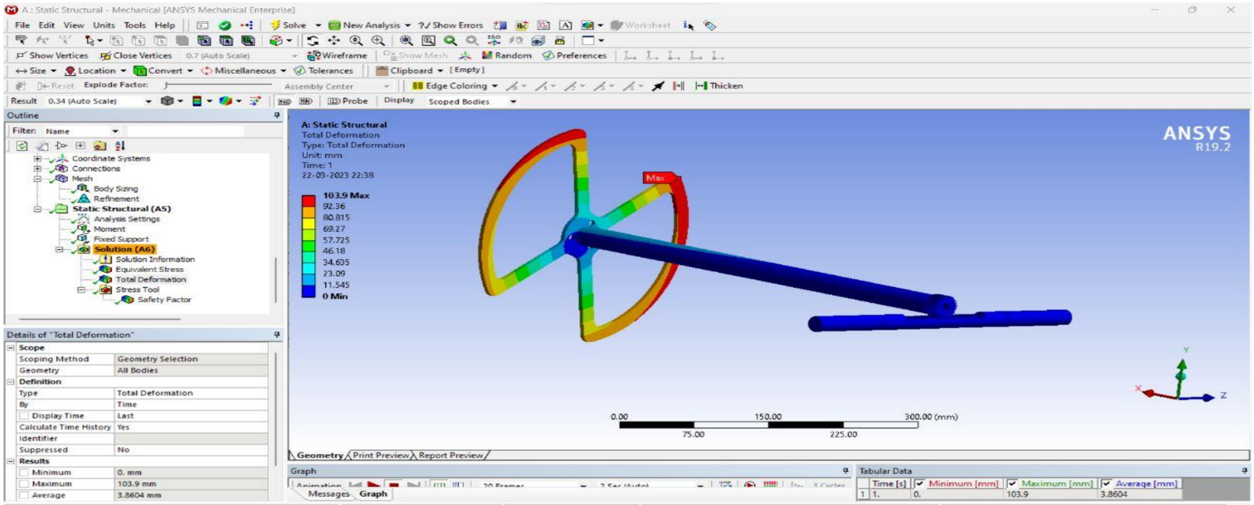

Figure 25 static structural analysis for total deformation

Stress analysis is a part of the machine design process for electric power steering that involves evaluating the stresses and strains that occur in the system's components due to its varied operating scenarios. This analysis ensures that the power steering system can withstand the loads and pressures it experiences in normal operation by locating potential failure and deformation locations.

Electric power steering stress analysis requires the use of complex computer-aided design (CAD) software and finite element analysis (FEA) tools for modelling and simulating the components of the system during the machine design process. The steering mechanism, electric motor, sensors, and electronic control unit will all be put through their paces in order to determine how well they withstand tension and compression, as well as how well they hold their shape under different conditions.

The results of a stress analysis can be used to make design changes that will increase the reliability and lifespan of a system by pinpointing areas where its components are at the greatest risk of failing or deforming. For instance, we may modify the design of a component or switch out its material to make it more suitable for the loads to which it will be subjected.

The stress study will also involve the evaluation of several other characteristics, including deflection, shear stress, and factor of safety. When a load is applied to a system, the components bend or deform to varying degrees. This is known as deflection. When a component is twisted or deformed by the action of two parallel forces acting in opposite directions, this is known as shear stress, which is defined as the force exerted per unit area.

Overall, electric power steering relies heavily on stress analysis during the machine design process. This study helps guarantee the system's security and dependability while also improving its design and performance.

Chapter 6: Conclusion

The quality of the power steering system's component parts has a significant impact on the efficiency of the system as a whole.

The evolution of the steering system began with the development of manual steering, then moved on to hydraulic power steering, and finally, electric power steering. In today's automotive market, electric power steering has surpassed both manual and hydraulic steering systems in terms of popularity. Because of its low weight and user-friendliness, electric power steering was the obvious option to go with. Large cars, on the other hand, almost always use power steering that is hydraulic. In this investigation, we will look at the many models for electric power steering that are now available and are based on dynamic motion equations. When a vehicle is equipped with electric power steering, the steering wheel can be turned with the assistance of a motor that acts as a booster.

It is possible to increase the effectiveness of power steering systems by decreasing the amount of force that is applied to the steering wheel by the motor. There are a number of potential ways for accomplishing this objective, including the development of improved hydraulic pumps and electric motors, as well as the optimization of control algorithms used in active steering control systems.

There are a few other types of steering systems available, but the two most common ones are rack and pinion steering, which is used on cars and smaller trucks and SUVs, and recirculating ball steering, which is used for bigger vehicles, trucks, and larger SUVs. There are a few other types of steering systems available, but these two are the most common ones.

This research is extremely significant to the automobile industry since power steering systems play an essential part in enhancing both the safety of vehicles and the quality of the driving experience they provide. A power steering system that has been meticulously designed and thoroughly optimized can successfully suit the requirements of both drivers and manufacturers. The research will be of assistance to the ongoing push to promote vehicle safety and lessen the negative consequences that the automobile industry has on the environment. The ultimate objective is to design a power steering system that assists the driver in steering with precision and responsiveness, all the while maintaining high levels of safety and dependability, increasing the vehicle's handling, and reducing costs and complexity to a minimum.

1234

ORIGINALITY REPORT

8%	5%	3%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	cartreatments.com Internet Source	1 %
2	W. Kemmetmuller, A. Kugi, S. Muller. "Modeling and Nonlinear Control of an Electrohydraulic Closed-Center Power-Steering System", Proceedings of the 44th IEEE Conference on Decision and Control, 2005 Publication	1 %
3	wa.co-aol.com Internet Source	<1 %
4	www.ijser.org Internet Source	<1 %
5	Submitted to Oxford Brookes University Student Paper	<1 %
6	Submitted to Universidad de Valladolid Student Paper	<1 %
7	glisc.info Internet Source	<1 %

8	fsd71.revistapasajes.com Internet Source	<1%
9	sci-hub.se Internet Source	<1%
10	vtechworks.lib.vt.edu Internet Source	<1%
11	Submitted to University of Newcastle upon Tyne Student Paper	<1%
12	Submitted to University of Western Sydney Student Paper	<1%
13	primalgrowpro.shop Internet Source	<1%
14	Zhao Yan, Li Fei. "Research on dynamic behavior of EPS based on frequency response and step response", 2010 5th International Conference on Computer Science & Education, 2010 Publication	<1%
15	Submitted to University of Lancaster Student Paper	<1%
16	T. Acarman, K.A. Redmill, U. Ozguner. "A robust controller design for drive by wire hydraulic power steering system", Proceedings of the 2002 American Control Conference (IEEE Cat. No.CH37301), 2002	<1%

Publication

17	fourcornersdailypost.com Internet Source	<1 %
18	Bong-Choon Jang, Gyoojae Choi. "Co-simulation and simulation integration for a full vehicle dynamic system", Mathematical and Computer Modelling of Dynamical Systems, 2007 Publication	<1 %
19	Submitted to Universiti Teknologi MARA Student Paper	<1 %
20	sistemasenha.novomilenio.br Internet Source	<1 %
21	Submitted to University of East London Student Paper	<1 %
22	link.springer.com Internet Source	<1 %
23	Submitted to UNITEC Institute of Technology Student Paper	<1 %
24	www.opel.ie Internet Source	<1 %
25	Submitted to School of Business and Management ITB Student Paper	<1 %
26	Submitted to University of Portsmouth Student Paper	

<1 %

27	etd.aau.edu.et Internet Source	<1 %
28	kagawa-u.repo.nii.ac.jp Internet Source	<1 %
29	web.deu.edu.tr Internet Source	<1 %
30	www.generacity.com Internet Source	<1 %
31	www.lexus-tech.eu Internet Source	<1 %
32	1library.net Internet Source	<1 %
33	G. Arcidiacono, R. Capitani. "Guidelines for defining a design standard for an electrical steering system", Journal of Engineering Design, 2002 Publication	<1 %
34	Xia Chang-gao. "Realization of Control Algorithm for Electro-Hydraulic Power Steering System Based on MC9S08AW32 Microcontroller", Advances in Intelligent and Soft Computing, 2011 Publication	<1 %

35	Zeng Qun, Huang Juhua. "Modeling and Simulation of the Electric Power Steering System", 2009 Pacific-Asia Conference on Circuits, Communications and Systems, 2009 Publication	<1 %
36	www.mercedes-benz.co.id Internet Source	<1 %
37	Wanzhong Zhao. "Chapter 4 Electro Hydraulic Hybrid Power Steering System", Springer Science and Business Media LLC, 2023 Publication	<1 %
38	Gevindu Wickramaarachchi, Melanie Amarasooriya. "Robotic assistance for the endoscopic steering", 2020 IEEE 8th R10 Humanitarian Technology Conference (R10-HTC), 2020 Publication	<1 %
39	M. Parmar, J.Y. Hung. "A Sensorless Optimal Control System for an Automotive Electric Power Assist Steering System", IEEE Transactions on Industrial Electronics, 2004 Publication	<1 %