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Fabrication of Electrical Steering Mechanism

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Abstract: in an automobiles the advanced requirements ' has been developing in a vehicle day by day such as dynamics control, comfort, safety etc. The total control of the vehicle will be based on the steering system. Now present days the vehicles are having the comfort steering system i.e., power steering in this present paper are discussing about the advanced steering system i.e., electrical steering system. Based on these requirements' the new functions are realized by various additional electrical components for measuring the signal processing and actuator control. The realization of the safety driving requires both experience and expertise in design and mass production of electrical steering systems relevant to power steering systems. Beside system safety and system availability the redundant electrical systems also have to meet economic and market requirements. We discussed below full steer-by wire system Full steer-by-wire system
This paper presents solutions for these systems and discusses the various advantages and disadvantages, and comparing of the three steering systems (manual steering, power steering, electrical steering) respectively. Furthermore strategies for failure detection, failure localization and failure treatment are presented. Finally the various specifications for the components used are discussed.
Key words: power steering, safety driving, electrical steering

I. INTRODUCTION

Steering system: It is the system which provides directional change in the performance of an automobile. This system converts rotary movement of the steering wheel into angular movement of the front wheels. It multiplies driver's effort by mechanical advantage, enabling him to turn the wheels easily.

A. Steering system requirements and functions

For proper and smooth operation and performance of the system, the steering system of any vehicle should fulfill the following requirements:

1) It should multiply the turning effort applied on the steering wheel by the driver.
2) It should be to a certain extent irreversible. In other words, the shocks of the road surface encountered by the wheels should not be transmitted to the driver's hands.
3) The mechanism should have self rightening effect i.e., when the driver releases the steering wheel after negotiating the turn, the wheel should try to achieve straight ahead position. Types of steering system:

B. Steering system is of the following types

1) Fifth wheel steering system
2) Side pivot steering system.

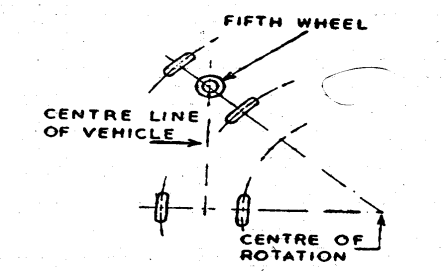


Fig 1.1 fifth wheel steering system

It is single pivot steering system in which the front axle along with the wheels, moves to right or left. The movement to the whole axle and wheel assembly is affected by means of a steering and a wheel which is placed between chassis frame and axle. The fifth

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wheel acts as a turntable. The axle assembly is connected with the frame by means of a pin which serves as a pivot around which the axle assembly moves. The fifth wheel contains a ring gear mounted at its rim and is moved by means of a steering. Movement of the steering wheel tends the front axle and wheel assembly to move away.

C. SIDE PIVOT STEERING MECHANISM:

There are two types of steering gear mechanisms:

1) Davis steering gear mechanism
2) Ackermann steering gear mechanism

The main difference between the two steering gear mechanisms is that the Davis steering has sliding pairs, whereas the Ackermann steering has only turning pairs. The sliding pair has more friction than the turning pair; therefore the Davis steering gear will wear out earlier and become inaccurate after certain time. The Ackermann steering gear is not mathematically accurate except in three positions, contrary to the Davis steering gear which is mathematically correct in all positions. However, the Ackermann steering gear is preferred to the Davis steering gear

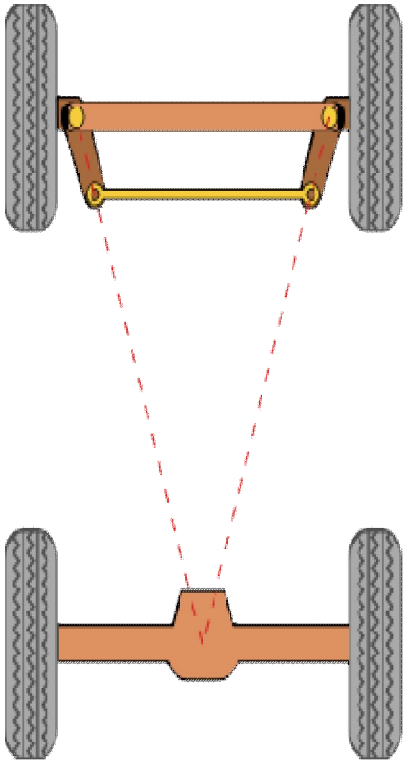


Fig1.2 Ackermann steering system

D. Ackermann Steering Gear

The Ackermann steering gear mechanism consists of a cross link KL connected to the short axles AC and BD of the two front wheels through the short arms AK and BL, forming bell crank levers CAK and DBL respectively. When the vehicle is running straight, the cross link KL is parallel to AB, the short arm AK and BL both make angle α to the horizontal axis of chassis. In order to satisfy the fundamental equation for correct steering, the links AK and KL are suitably proportioned and angle α is suitably selected.

For correct steering

$\cot \varphi - \cot \theta = b / l$

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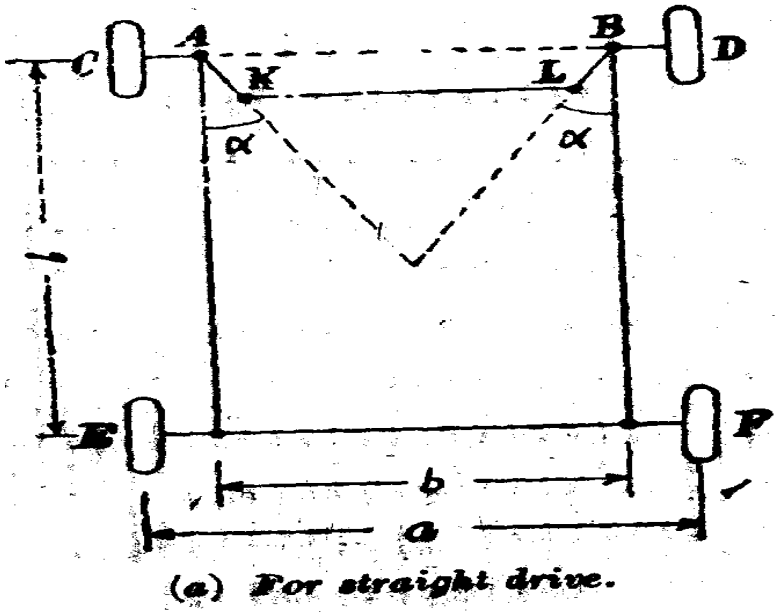
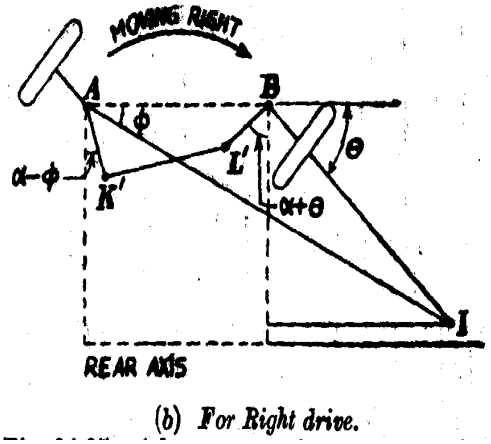


Fig 1.3 Straight drive



The angles φ and θ are shown in the Figure. The value of b / l is between 0.4 and 0.5, generally 0.455. the value of cot φ – cot θ corresponds to the positions when the steering is correct. In fact there are three values of angle θ which give correct steering of the vehicle: first while it is turning to right, second while it is turning to left and third while it is running straight.Referring to Fig, for correct steering,

$$\cot\varphi = \frac{y+c}{b} \qquad (\varphi = \text{angle of inside lock})$$

$$= \frac{y}{b} + \frac{c}{b} = \cot\theta + \frac{c}{b} \qquad (\theta = \text{angle of outside lock})$$

$$\therefore \quad \cot\varphi - \cot\theta = \frac{c}{b}$$

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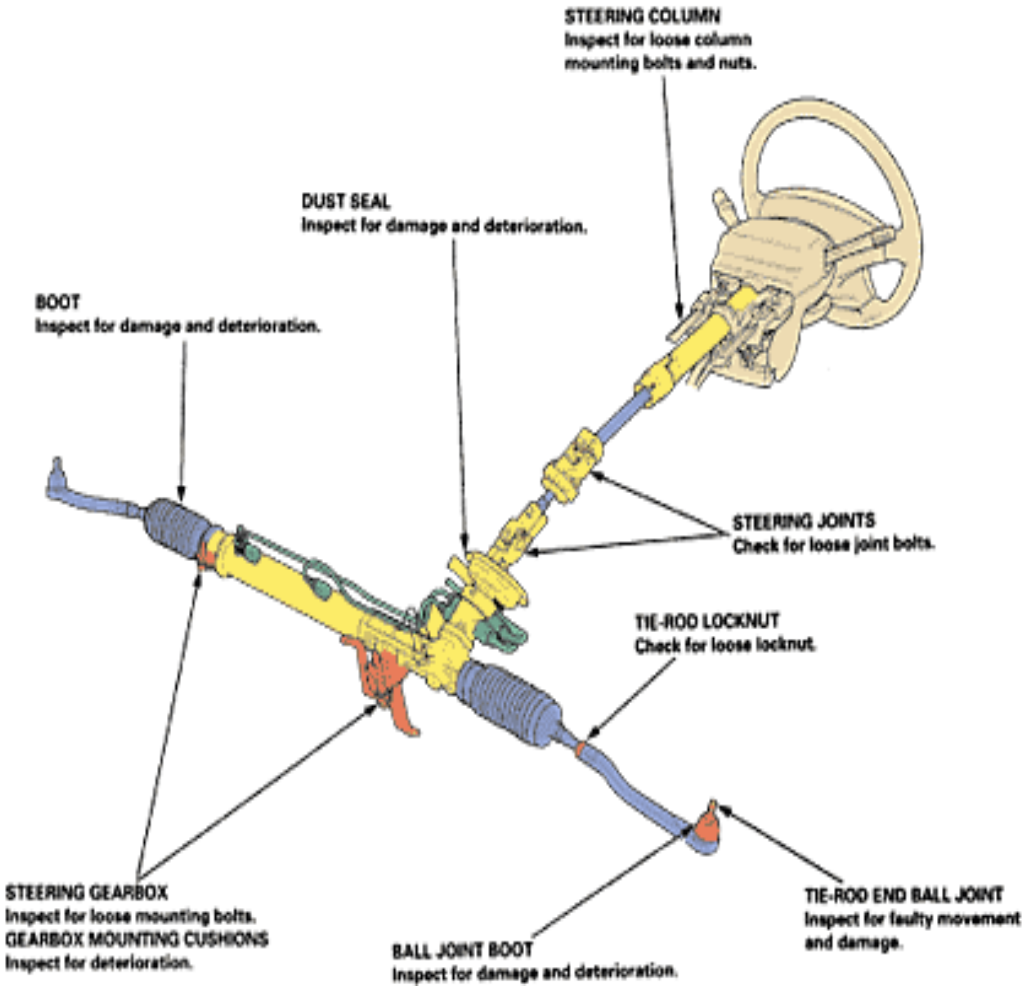


Fig 1.5 Components of steering system

II. STEERING WHEEL

Steering is effected by the steering wheel. The steering wheels of commercial vehicles have a metal armature comprised of a screw machined hub with metal spokes and rim. The hub, spokes and rim are all fabricated into one piece by welding. The armature serves as the load bearing structure of the wheel. The armature is surrounded by a molded rubber or plastic material. Rubber wheels are painted, and plastic wheels utilize impregnated colors.

The steering wheel is of large diameter. This helps to convert the available driver rim pull into maximum input torque. However, the size of the wheel is limited by the following: (1) The comfort of the driver when using the steering wheel. (2) The space available for the steering in the interior of the cabin. (3) The ease of performing maneuvers requiring more than an eighth of a turn of the steering wheel.

The diameter of the steering wheel lies between 42 and 45 cm the case of motor cars, whereas it is 50 to 55 cm in the case of commercial vehicles.

The rim of the steering wheel is elliptical in cross section with the finger indentations on the undersurface. The section of the rim is so designed and dimensioned to provide the driver a good grip both with and without heavy gloves.

A. Manual steering system

Manual steering is considered to be entirely adequate for smatter vehicles. It is tight. fast, and accurate in maintaining steering control. However, larger and heavier engines. greater front overhang on larger vehicles, and a trend toward wide tread tires have increased the steering effort required. Steering mechanisms with higher gear ratios were tried, but dependable power steering systems were found to be the answer. There are several different types of manual steering systems, which are as follows:

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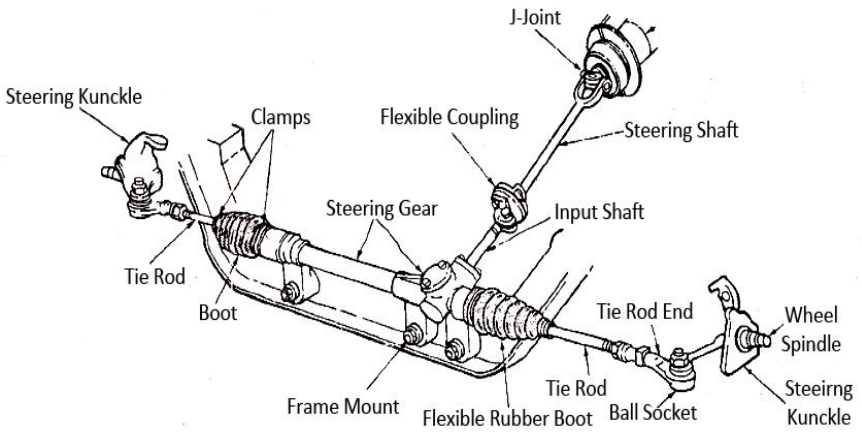


Fig 1.6 manual steering components

Manual steering is a system in which manual force is used for steering. Mechanism manual steering rack uses a rack and pinion, worm and roller and recirculation ball and andnut. it is comaparetevly slow and resistance to wheel moment is more .
Elements; steering wheel and column a manual gear box and pit man arm or a rick and pinion assembley,linkages steering knuckles and ball joints and the wheel spindle assemblies.

1) *Advantages of manual steering:*Mechanical connection between the steering wheel and the wheel and the components continues to be mintedwithout the help of auxiliary power and preferred incomponents continues to be maintainedwithout the help of the auxiliary power and preferred in race cars
2) *Manual Steering Systems :*Manual steering is considered to be entirely adequate for smatter vehicles. It is tight. fast, and accurate in maintaining steering control. However, larger and heavier engines.greater front overhang on larger vehicles, and a trend toward wide tread tires have increased the steering effort required. Steering mechanisms with higher gear ratios were tried, but dependable power steering systems were found to be the answer. There are several different types of manual steering
3) *Worm and sector* **:**In the worm and sector steering gear (fig. 8-20), the pitman arm shaft carries the sector gear that meshes with the worm gear on the steering gear shaft. Only a sector of gear is used because it turns through an arc of approximately 70 degrees. The steering wheel turns the worm on the lower end of the steering gear shaft, which rotates the sector and the pitman arm through the use of the shaft. The worm is assembled between tapered rotter bearings that take up the thrust and toad.

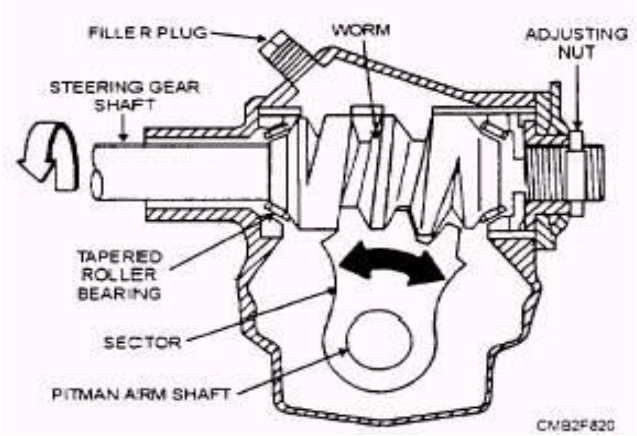


Fig 1.7 Worm and sector

B. Worm and Roller

The worm and rotter steering is quite similar to the worm and sector, except a roller is supported by ball or rotter bearings within the sector mounted on the pitman arm shaft. These bearings assist in reducing sliding friction between the worm and sector. As the steering wheel turns the worm, the roller turns with it, forcing the sector and pitman arm shaft to rotate.The hourglass shape of the

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worm, which tapers from both ends to the center, affords better contact between the worm and roller in all positions. This design provides a variable steering ratio to permit faster and more efficient steering.

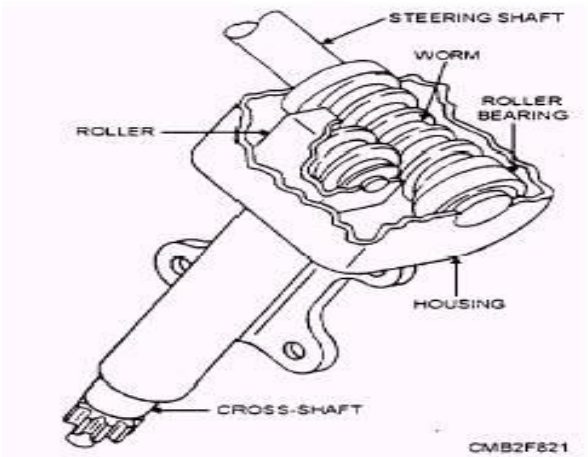


Fig 1.8 Worm and roller

C. Power steering:

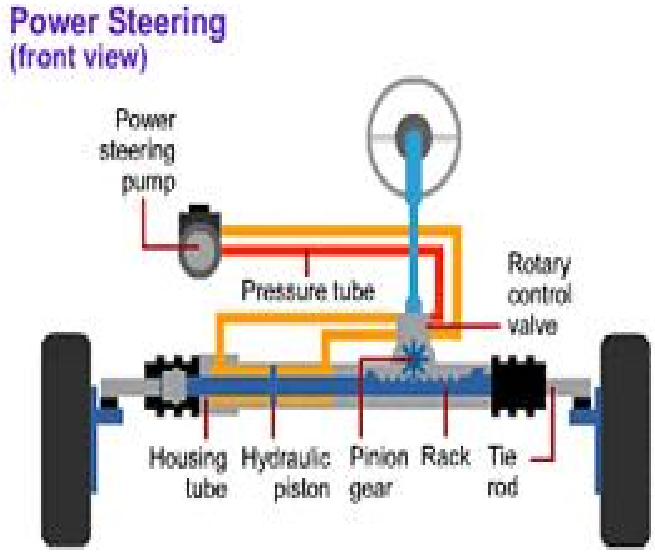


Fig 1.9 power steering

Power steering is a system that helps in steering the wheels by using power of engine. manual steering is a system in which manual force is used for steering. Steering refers to the mechanism of guiding g the wheels towards the intended direction you must be filmier with the steering. Systems of car. The drivers uses the steering to control the course taken by wheels .power steering is a system that helps in steering the wheel by using power of engine however today most of the cars are using power steering system.
Mechanism: hydraulic rack and pinion, recirculation ball and nut, worm and roller hydrostatic electrical rack and pinion, column driven esp., pinion drives esp., rack drives esp. Resistance to wheel moment is less.
Elements: a hydraulic pump, fluid reservoir, hoses lines; and either a power assist unit mounted and a power steering gear assembly

III. ELECTRICAL POWER STEERING

Electric Power Steering (EPS) has replaced hydraulic power steering in many new vehicles today. One of the advantages of electric power steering is that it eliminates the power steering pump, which can use as much as 8 to 10 horsepower under load. This improves fuel economy while also eliminating the weight and bulk of the power steering pump and hoses. Getting rid of the

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hydraulics also does away with fluid leaks and the need to check the power steering fluid. Electric power steering is also quieter than hydraulic systems because there is no pump noise and no fluid flowing through hoses and valves. But the most noticeable difference is in handling and steering refinement.

Electric power steering can be fine tuned with a precision that is hard to match with hydraulic controls. By monitoring the driver's steering inputs, vehicle speed, and other suspension dynamics, the system can provide just the right amount of steering feel and effort to match rapidly changing driving conditions. EPS can deliver extra effort when you need it, and reduce steering effort when you do not need it. It can even provide steering assist when the engine is off.
EPS systems have variable power assist, which provides more assistance at lower vehicle speeds and less assistance at higher speeds. They do not require any significant power to operate when no steering assistance is required. For this reason, they are more energy efficient than hydraulic systems.

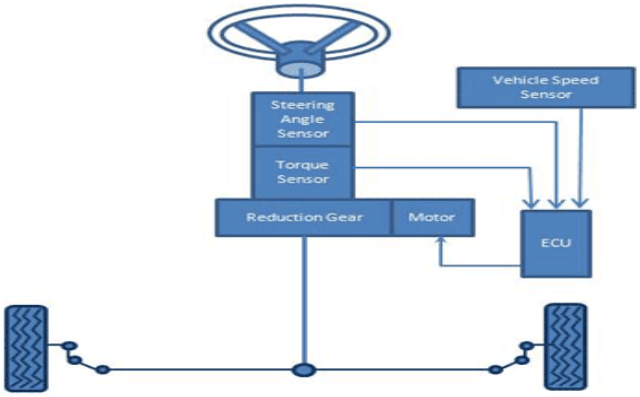


Fig 3.1 electrical power steering

A. How Electric Power Steering Works

Though some of the older electric power steering systems were actually "electro-hydraulic," and used an electric motor to drive a conventional hydraulic pump, the latest generation of EPS is all electric/electronic. The steering gear itself is a manual rack with an electric motor mounted on the steering column or the rack.

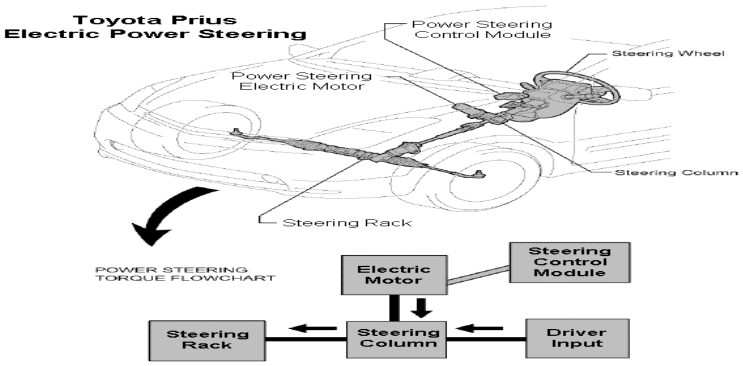


Fig 3.2 working of electrical power steering

B. Chevy Cobalt Electric Power Steering Modes

The General Motors EPS system has several modes of operation:

1) *Normal mode* -- Left and right assist is provided in response to inputs and vehicle speed.
2) *Return mode* -- Used to assist steering return after completing a turn. Feedback from the steering position sensor prevents the EPS system from "overshooting" the center position.
3) *Damper control mode* -- Used to improve road feel and dampen kickback. This mode typically kicks in at higher vehicle speeds.

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4) *Protection mode* -- Protects electrical components from thermal damage and excessive current flow if the steering is held all the way to one side in the lock position too long.

Turning the steering wheel all the way to one side will cause the Power Steering Control Module (PSCM) to command the maximum amount of current to the EPS motor. If the steering wheel is then held in this position for an extended period of time, the system will go into protection mode so the motor doesn't overheat. In this mode, the PSCM will limit the amount of current to the motor and reduce the level of power assist.

5) *Steer-by-wire system;*The main feature of future steering systems is the missing direct mechanical link between steering wheel and steered wheels. With such a steer-by-wire steering system Fig. 3.1 the missing steering column's function must be reproduced in both directions of action. In forward direction the angle set by the driver at the steering wheel is measured by a steering angle sensor and transferred with the suitable steering ratio to the wheels. In reverse direction the steering torque occurring at the wheels is picked up via a torque sensor and attenuated respectively, modified fed back to the driver as a counter torque on the steering wheel.

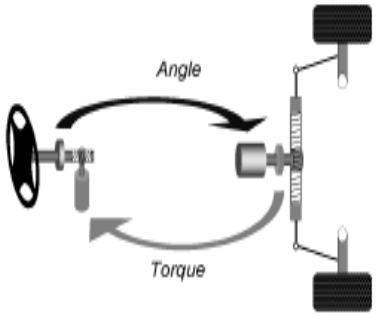


Fig 3.3 Principle illustration steer-by-wire

First, steering wheel module and steering module are implemented with familiar components of mechanical and electrical steering systems, like: Steering wheel, gearbox, electrical motors, rack. The operational principle is, however, in principle open for more futuristic designs like side stick operation on the driver's side and single wheel steering on the wheel side. While in systems with mechanical connection in the case of electrical errors only the steering boost is concerned, corresponding measures must be taken with steer-by wire systems that in case of any electrical failure steering control is always guaranteed.

C. Dc Motors

Almost every mechanical movement that we see around us is accomplished by an electric motor. Electric machines are a means of converting energy. Motors take electrical energy and produce mechanical energy. Electric motors are used to power hundreds of devices we use in everyday life. Motors come in various sizes. Huge motors that can take loads of 1000's of Horsepower are typically used in the industry. Some examples of large motor applications include elevators, electric trains, hoists, and heavy metal rolling mills. Examples of small motor applications include motors used in automobiles, robots, hand power tools and food blenders. Micro-machines are electric machines with parts the size of red blood cells, and find many applications in medicine.

Electric motors are broadly classified into two different categories: DC (Direct Current) and AC (Alternating Current). Within these categories are numerous types, each offering unique abilities that suit them well for specific applications. In most cases, regardless of type, electric motors consist of a stator (stationary field) and a rotor (the rotating field or armature) and operate through the interaction of magnetic flux and electric current to produce rotational speed and torque. DC motors are distinguished by their ability to operate from direct current.

D. Electromechanical Energy Conversion

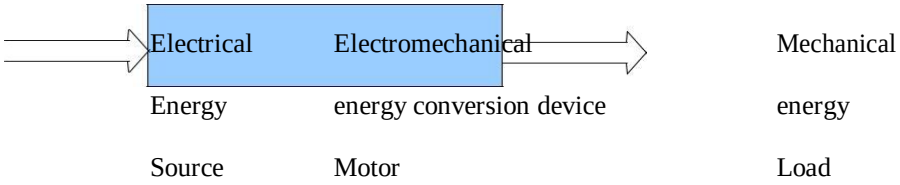
An electromechanical energy conversion device is essentially a medium of transfer between an input side and an output side. Three electrical machines (DC, induction and synchronous) are used extensively for electromechanical energy conversion. Electromechanical energy conversion occurs when there is a change in magnetic flux linking a coil, associated with mechanical motion.

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E. Electric Motor

The input is electrical energy (from the supply source), and the output is mechanical energy (to the load).



F. Electric Generator

The Input is mechanical energy (from the prime mover), and the output is electrical energy.

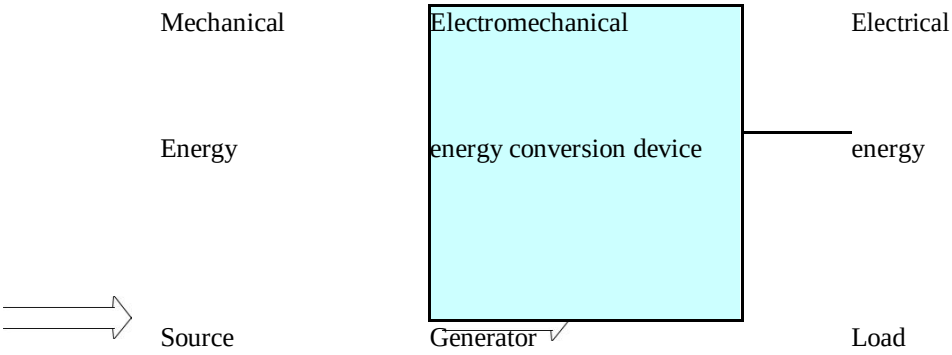


Figure. 2

G. Construction

DC motors consist of one set of coils, called armature winding, inside another set of coils or a set of permanent magnets, called the stator. Applying a voltage to the coils produces a torque in the armature, resulting in motion.

H. Stator

The *stator* is the stationary outside part of a motor. The stator of a permanent magnet dc motor is composed of two or more permanent magnet pole pieces. The magnetic field can alternatively be created by an *electromagnet*. In this case, a DC coil (field winding) is wound around a magnetic material that forms part of the stator.

I. Rotor

The *rotor* is the inner part which rotates.

The rotor is composed of windings (called armature windings) which are connected to the external circuit through a mechanical commentator.

Both stator and rotor are made of ferromagnetic materials. The two are separated by air-gap.

J. Winding

A winding is made up of series or parallel connection of coils.

Armature winding - The winding through which the voltage is applied or induced.Field winding - The winding through which a current is passed to produce flux (for the electromagnet) Windings are usually made of copper.

K. Energy Conversion

If electrical energy is supplied to a conductor lying perpendicular to a magnetic field, the interaction of current flowing in the conductor and the magnetic field will produce mechanical force (and therefore, mechanical energy).

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L. Value of Mechanical Force

There are two conditions which are necessary to produce a force on the conductor. The conductor must be carrying current, and must be within a magnetic field. When these two conditions exist, a force will be applied to the conductor, which will attempt to move the conductor in a direction perpendicular to the magnetic field. This is the basic theory by which all DC motors operate.
The force exerted upon the conductor can be expressed as follows.

$$F = B\,i\,l \text{ Newton} \qquad (1)$$

where B is the density of the magnetic field, *l* is the length of conductor, and *i* the value of current flowing in the conductor. The direction of motion can be found using Fleming's Left Hand Rule.

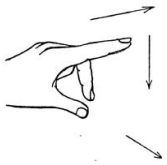


Figure 3: Fleming's Left Hand Rule

The first finger points in the direction of the magnetic field (first - field), which goes from the North pole to the South pole. The second finger points in the direction of the current in the wire (second - current) . The thumb then points in the direction the wire is thrust or pushed while in the magnetic field (thumb - torque or thrust).

M. Principle of operation

Consider a coil in a magnetic field of flux density **B** (figure 4). When the two ends of the coil are connected across a DC voltage source, current I flows through it. A force is exerted on the coil as a result of the interaction of magnetic field and electric current. The force on the two sides of the coil is such that the coil starts to move in the direction of force.

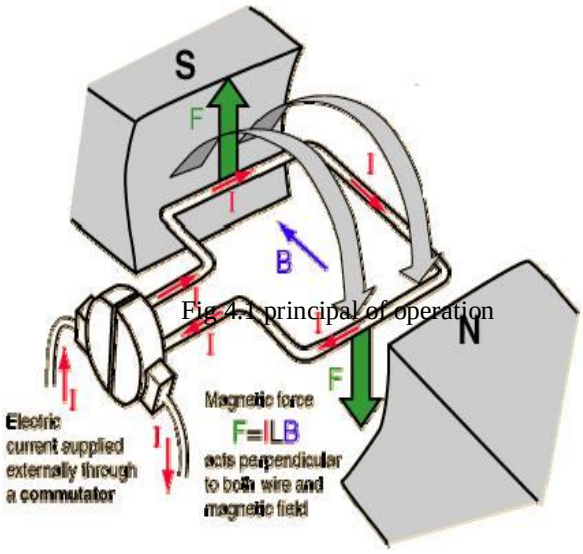


Fig 4.1 principal of operation

Torque production in a DC motorIn an actual DC motor, several such coils are wound on the rotor, all of which experience force, resulting in rotation. The greater the current in the wire, or the greater the magnetic field, the faster the wire moves because of the greater force created.At the same time this torque is being produced, the conductors are moving in a magnetic field. Atdifferent positions, the flux linked with it changes, which causes an Emf to be induced (e = d /dt) as shown in figure 5. This voltage is in opposition to the voltage that causes current flow through the conductor and is referred to as a counter-voltage or back Emf.

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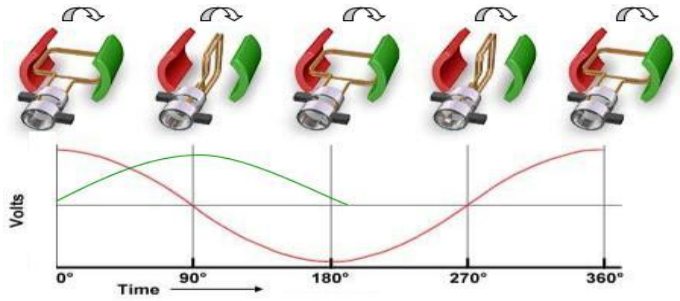


Fig 4.2: Induced voltage in the armature winding of DC motor

The value of current flowing through the armature is dependent upon the difference between the applied voltage and this counter-voltage. The current due to this counter-voltage tends to oppose the very cause for its production according to Lenz's law. It results in the rotor slowing down. Eventually, the rotor slows justenough so that the force created by the magnetic field (*F = Bill*) equals the load force applied on the shaft. Then the system moves at constant velocity.

N. Torque Developed

The equation for torque developed in a DC motor can be derived as follows.
The force on one coil of wire $F=il$ x B Newton
Note that l and B are vector quantities
Since $B = /A$ where A is the area of the coil,
Therefore the torque for a multi turn coil with an armature current of I_a:

$$T = K\ I_a \qquad (2)$$

Where is the flux/pole in weber, K is a constant depending on coil geometry, and I_a is the current flowing in the armature winding.

Note: Torque T is a function of force and the distance, equation (2) lumps all the constant parameters (eg. length, area and distance) in constant K.

The mechanical power generated is the product of the machine torque and the mechanical speed of rotation, $_m$ Or, $P_m = {}_mT$

$$= {}_mK\ I_a \qquad (3)$$

It is interesting to note that the same DC machine can be used either as a motor or as a

generator, by reversing the terminal connections.

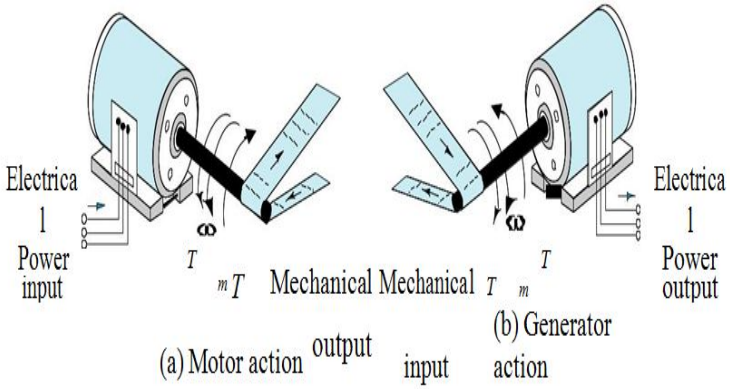


Fig4.3: Reversibility of a DC machine

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O. Induced Counter-voltage (Back emf):

Due to the rotation of this coil in the magnetic field, the flux linked with it changes at different positions, which causes an *emf* to be induced (refer to figure 5).

The induced emf in a single coil, $e = d_c/dt$

Since the flux linking the coil, $_c$ = Sint

Induced voltage:*e* = *Cos*

P. DC Machine Classification

DC Machines can be classified according to the electrical connections of the armature winding and the field windings. The different ways in which these windings are connected lead to machines operating with different characteristics. The field winding can be either self-excited or separately-excited, that is, the terminals of the winding can be connected across the input voltage terminals or fed from a separate voltage source (as in the previous section). Further, in self-excited motors, the field winding can be connected either in series or in parallel with the armature winding. These different types of connections give rise to very different types of machines, as we will study in this section.

Q. Separately excited machines

The armature and field winding are electrically separate from each other. The field winding is excited by a separate DC source.

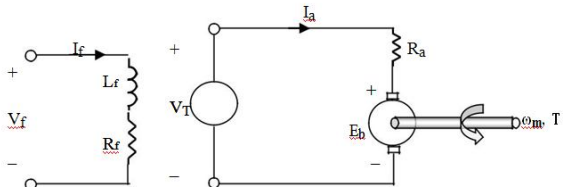


Fig4.4 separately excited machine

The voltage and power equations for this machine are same as those derived in the previous section.

Note that the total input power = $V_f I_f + V_T I_a$

R. Shunt machine

The armature and field winding are connected in parallel. The armature voltage and field voltage are the same.

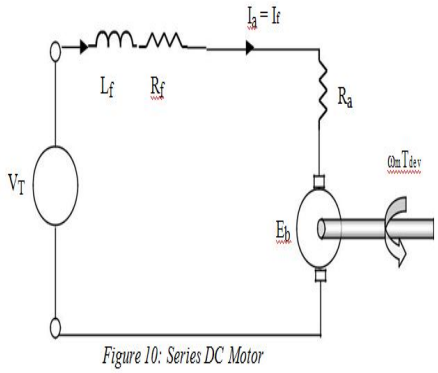


Figure 10: Series DC Motor

Fig 4.5 shunt machine

Notice that in this type of motor,

Total current drawn from the supply, $I_L = I_f + I_a$

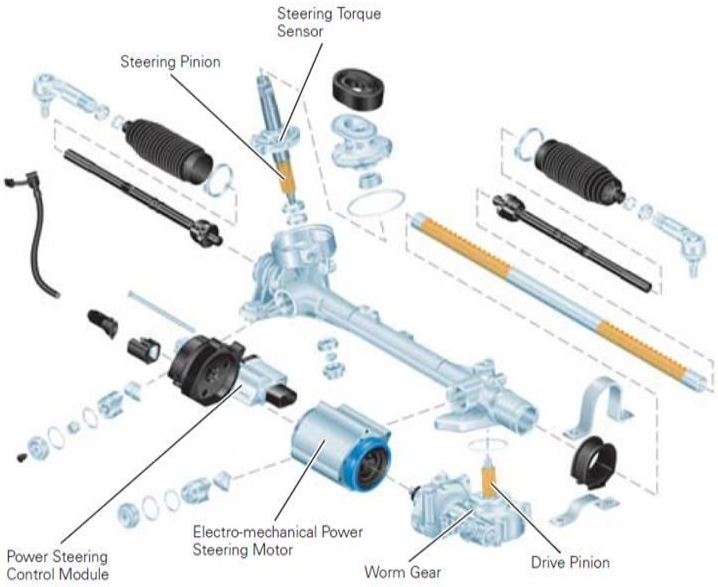
Total input power = $V_T I_L$

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IV. COMPONENTS OF ELECTRICAL STEERING

System overview



A. Functional Description

In an electrical power steering system the steering torque initiated by the driver Fig. 4.1 is measured by a steering wheel torque sensor and is fed into an electronic control unit. The latter then calculates along with the driving speed a reference torque for the steering motor, which, however, can optionally also depend on the steering angle and steering angle velocity. By means of the calculated reference torque the currents of the steering motor are actuated. Fig. 4.1 shows the pinion-type realization, where at the pinion the electrical torque is superimposed to the torque initiated by the driver. In further versions both torques can be superimposed either on the steering column or on the rack. In case of a failing electrical component of this steering system the non-boosted mechanical intervention by the driver is maintained.

B. System Structure Of Steer-By-Wire System With Hydraulic Backupfunctional Description

The steer-by-wire system with hydraulic backup is shown in Fig.4.2. The system consists of components at the steering wheel and at the vehicle wheel level, an electronic control unit and a hydraulic backup. Steering wheel motor and sensors for the steering wheel angle and the steering wheel torque are arranged at the steering wheel. These components identify the driver's desire and reproduce the return forces to the steering wheel, which are transferred to the steering wheel by conventional steering systems. These feedback forces are important to gain a safe feeling while driving. At the vehicle wheels side the system consists of an electric motor directing the mechanically coupled wheels via a gear and a rack, and of sensors to measure angles and torques. The electronic control unit registers periodically all sensor values, processes them via efficient control algorithms and supplies the control signals to actuate the motors. Via a serial data bus, the electronic control unit communicates with a vehicle guidance unit, which coordinates the superior steering interventions, e.g. to improve vehicle dynamics. This unit at the same time constitutes an interface to the driver information system, and to additional control units for engine and brakes. The control unit in Fig. 4.2 is presented as a central control unit. It can also be divided into two modules arranged close to the steering wheel and steering motor, and connected to a data bus system for communication. A closed hydraulic unit, consisting of a hydraulic pump at the steering wheel and a plunger on the vehicle wheel level, constitutes the backup. Both sides of these components are connected with each other by hydraulic lines. During normal operation the plunger is bypassed. In case of failure, the fail-safe switching valve actuated by the electronic control unit will close the bypass. Thus, via the hydraulic backup, the steering

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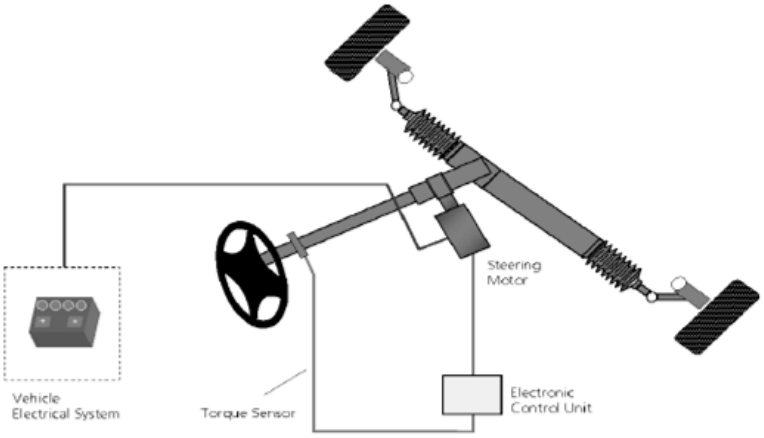


Figure 4.9 System structure of Electric Power Steering

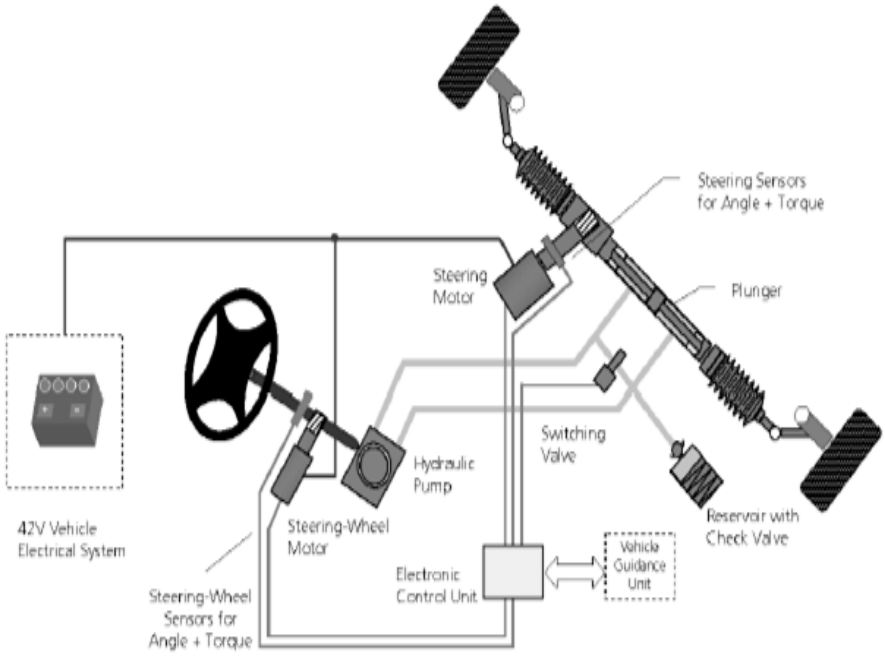


Figure 4.10 System structure of steer-by-wire system with hydraulic backup

actuator can be operated by means of the steering wheel. Without electric current, the switching valve must be closed. In case of failure of the 42V vehicle electrical system thus the hydraulic bypass is automatically closed and the backup safely activated. If the steering wheel motor can still be controlled during backup operation it can be adequately actuated to support power steering. The increased pressure needed to operate the hydraulic backup is provided by means of a small pressure reservoir with check valve. This pressure accumulator compensates the leakage, which occurs during the vehicle lifetime. The pressure within the backup level is continuously monitored by a pressure or displacement sensor.

*C. System Structure Of The Purely Electrical Steer-By-Wire System*functional Description

Fig. 4.3 shows the structure of a purely electrical steering system. The reduced safety by omitting steering column and hydraulic backup is compensated by higher demands on the safety structure of electrical and electronic components. Again, the system consists of components at the steering wheel on the vehicle wheel level, and it comprises a control unit and a 42V vehicle electrical system. In this case this must be implemented as a safe 42V vehicle electrical system

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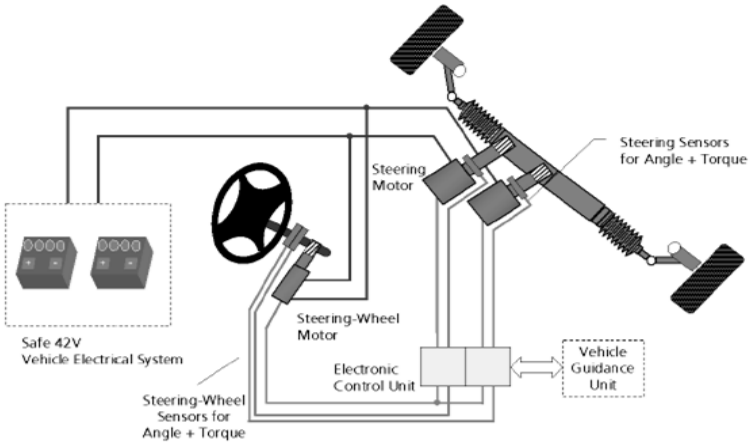


Figure 4.11 System structure of purely electrical steer-by-wire system

Containing additional elements for the diagnosis of charge condition, as well as for the disconnection of batteries.
The steering wheel motor and sensors indicating steering wheel angle and steering wheel torque are arranged at the steering wheel. These components identify the driver's desire and reproduce the return forces transferred to the steering wheel. For a safe acquisition of steering wheel position two redundant steering angle sensors are used. Power stage and power supply for the steering wheel motor are likewise redundant. In order to exert a return force on the steering wheel in case of a defective steering motor a torsion spring is available to generate the return torque. Optionally a second steering wheel motor can be used in order to redundantly generate the return torque. On the vehicle wheel level the system is equipped with a redundant set of electric motors and redundant sensors measuring angles and torques.

D. Proposed models



Fabrication of electrical steering mechanism



Fabrication of electrical steering mechanism

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V. CONCLUSION

This paper presents various types of electrical steering systems and their safety aspects. An electric motor is used, yielding energy savings and flexibility of installation. Electrical power steering pursues this trend and offers additional advantages since no hydraulic system is required. A purely electrical system was discussed. Future innovative steering functions, such as vehicle dynamic interventions, collision avoidance, individual wheel steering, tracking assistance, automatic lateral guidance, and finally autonomous driving functions will be implemented in a system compound of various vehicle systems. Future steering systems will thus have to be integrated into a system compound, in terms of interfaces and functions. The steer-by-wire principle becomes absolutely necessary when those innovative functions are to be achieved. The transition to purely electrical steering systems will proceed step by step, for safety reasons and acceptance by the customer. The path will lead from electrical power steering via a steer-by-wire system with a mechanical backup towards purely electrical steer-by-wire systems.

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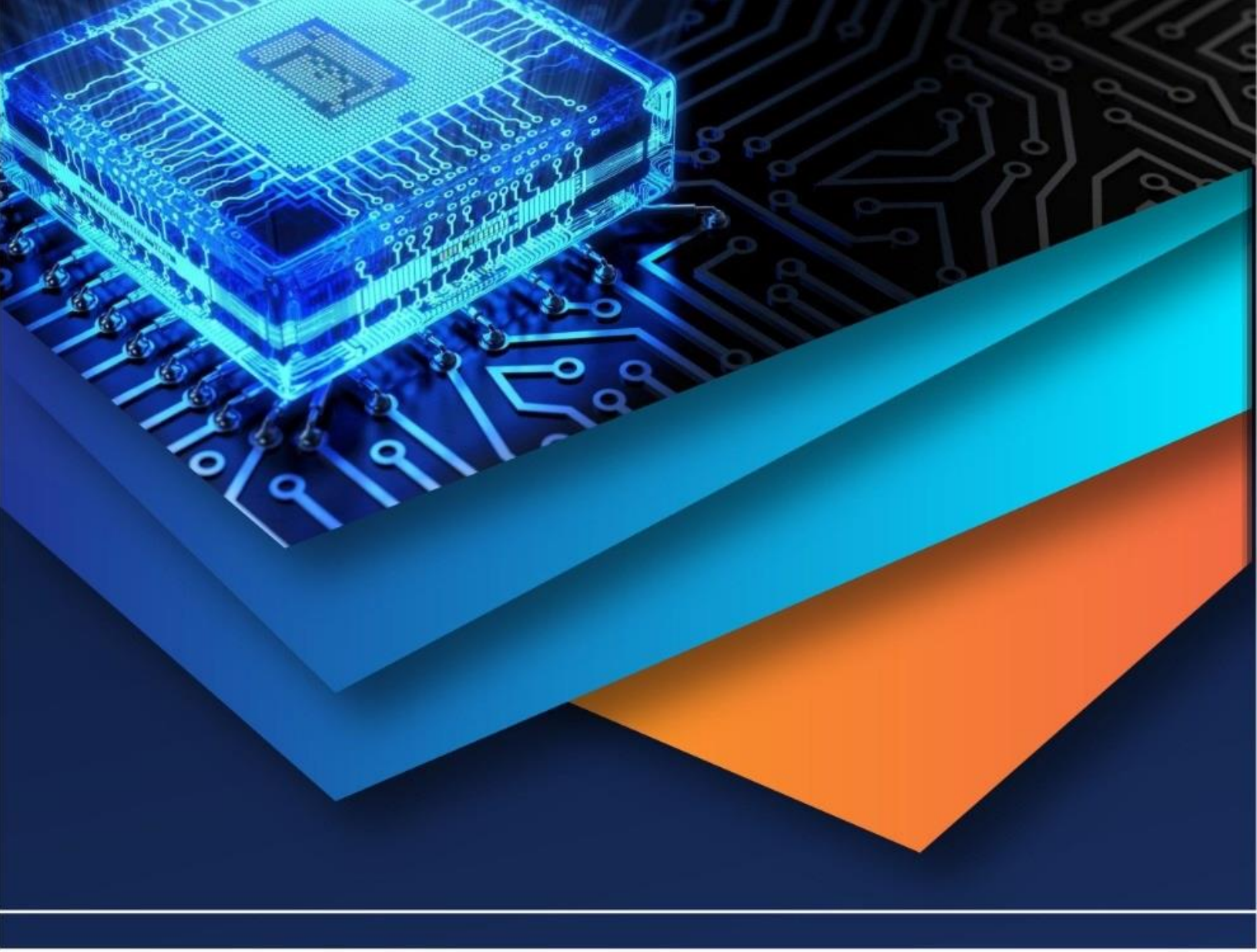
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