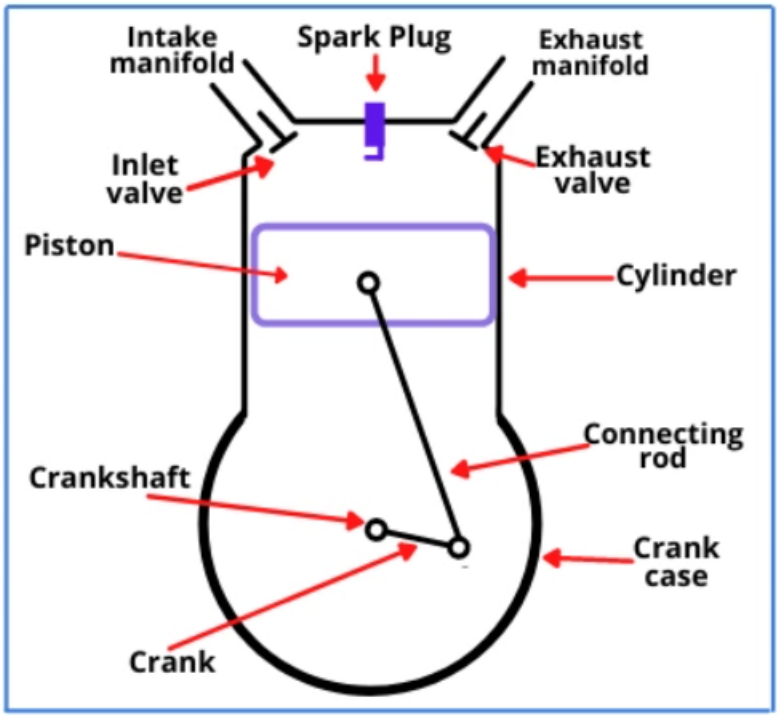
Automotive Fundamentals Overview:

Components of IC Engine



The main eight components of the IC engine are as follows:-

1. Piston
2. Cylinder
3. Inlet valve
4. Exhaust valve
5. Spark plug/Fuel injector
6. Crank
7. Camshaft
8. Crankshaft
9. Connecting Rod

1] Piston:- Piston plays the main role in the ic engine. The piston linearly moves from the TDC (Top dead center) to BDC (Bottom dead center) inside the cylinder to perform different work. There are piston rings are mounted on the piston which helps in sealing the combustion gases as well as to transfer of heat from piston to cylinder.

The piston is connected to the connecting rod with the help of a gudgeon pin. During the suction stroke, the piston helps to take fresh charge inside of the

chamber, during compression stroke helps to compress the charge while during the exhaust stroke helps to remove the burnt gases from the chamber through an engine exhaust valve.

2] Cylinder:- The cylinder is the part in which the piston moves. The combustion takes place inside the cylinder. During the suction stroke, the charge enters into the cylinder.

The inlet valve, exhaust valve, fuel injector/spark plug are mounted on the cylinder head.

3] Inlet valve:- The inlet valve is located at the engine intake port, from where the fresh charge enters inside the cylinder.

The inlet valve is open and closed by the rotation of the camshaft. The Inlet valve is in the open position during the suction stroke and remains closed during other strokes.

4] Exhaust valve:- The exhaust valve is located at the engine exhaust port, from where the exhaust gases are released to the exhaust manifold.

The opening and closing of the exhaust valve is also done by the rotation of the camshaft. The exhaust valve is in the open position only during the exhaust stroke and remains closed during the other strokes.

5] Spark plug/Fuel injector:- The petrol engines have spark plug while the diesel engines have the fuel injector.

The fuel injector is connected to the fuel intake. It sprays the fuel droplets inside the chamber after the air is compressed by the piston.

The spark plug is connected to the vehicle battery. When the piston compresses the air-fuel mixtures inside the cylinder, the spark plug produces the spark to ignite the fuel.

6] Crank:- One end of the crank is connected to the connecting rod and another end is connected to the crankshaft. The crank and connecting rod are helps in converting the linear motion of the piston into the rotary motion of the crankshaft.

7] Camshaft:- The camshaft is an engine inlet and exhaust valve operating mechanism. The camshaft is driven by the crankshaft through a timing belt or timing chain.

8] Crankshaft:- Crankshaft is a shaft that rotated due to the rotary motion of the crank.

The flywheel is located at one end of the crankshaft as well as another end has a pulley to transfer the power to the camshaft using a timing chain or timing belt.

9) Connecting rod:

These engine parts are provided to connect the piston to the crankshaft. Just as mentioned earlier, it converts the linear motion of the piston into the rotary motion of the crank. One of its end parts is attached to the piston through a piston pin also known as a gudgeon pin and wrist pin. Another end is attached to the crankpin journal using bolts to hold down the upper and lower bearing caps called the big end.

10) Rocker arm:

This internal combustion engine part plays an important role as it transmits the rotary motion of the cam or crankshaft through a tappet/latch and converts it into a linear motion of the valve stem, helping in depressing the valve head

The rocker head is made from steel stampings for light and medium-duty engines whereas the heavy-duty diesel engine rocker head is made of cast iron and forged carbon steel as it offers greater strength and stiffness. The rocker arms oscillate about a fixed pivot rod in the cylinder head.

11) Crankcase:

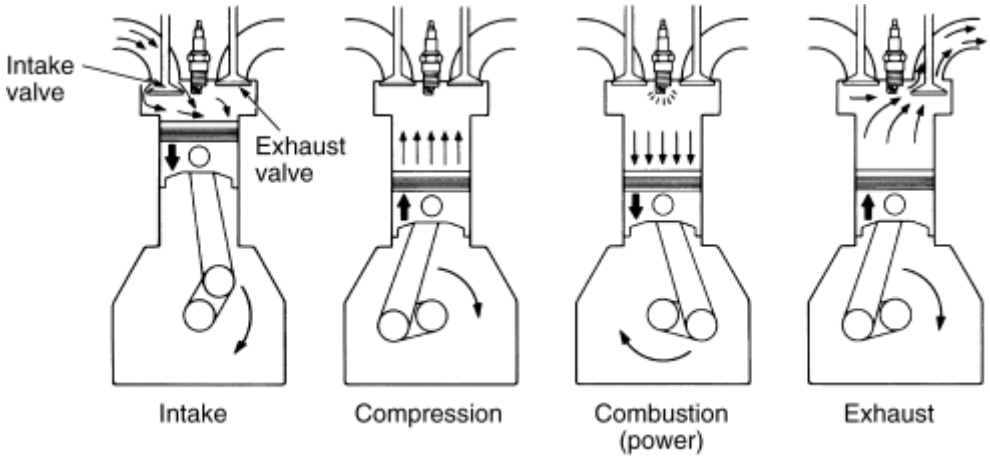
These internal combustion engine components are located below the cylinder block containing the bearings that rotate the crank. This main bearing is a sliding bearing with an adequate oil supply in it. Four-cylinder inline petrol engines contain three bearings in the crankcase, one at each end and one in the middle while diesel engines have five main bearings, one at each end and one between each cylinder.

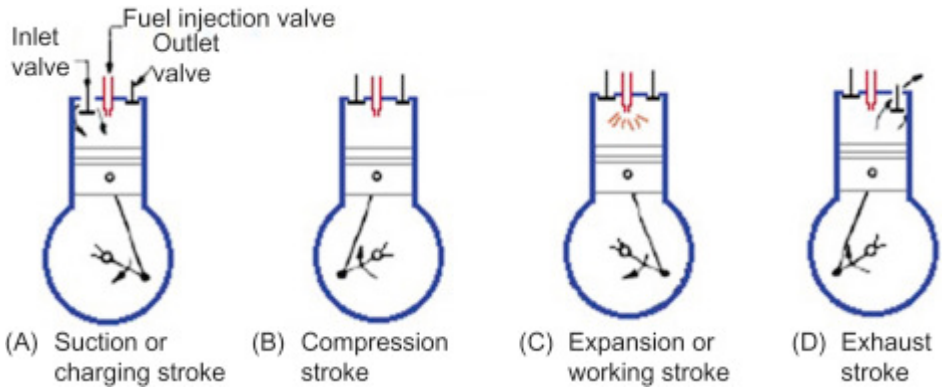
The crankcase is made from cast iron and aluminum the same material used in making the cylinder block. A crankcase serves many purposes to the engine as it helps to protect its inner mechanism from dust, dirt, and some other materials. It also serves as housing that encloses the crankshaft and the connecting rod, keeping the oil and air.

12. Oil pump and sump:

The function of the oil pump is to pumps the oil to various parts of the engine for proper lubrication, cleaning, and cooling. The oil pump in the engine is driven by the crankshaft gear. The oil is pressurized to various parts of the engine components, which helps in lubricating and cooling the system.

Four Stroke Cycle





A **four-stroke** (also **four-cycle**) **engine** is an internal combustion (IC) engine in which the piston completes four separate strokes while turning the crankshaft. A stroke refers to the full travel of the piston along the cylinder, in either direction. The four separate strokes are termed:

1. **Intake**: Also known as induction or suction. This stroke of the piston begins at top dead center (T.D.C.) and ends at bottom dead center (B.D.C.). In this stroke the intake valve must be in the open position while the piston pulls an air-fuel mixture into the cylinder by producing vacuum pressure into the cylinder through its downward motion. The piston is moving down as air is being sucked in by the downward motion against the piston.

   Key points

   - **Inlet Valve – Open**
   - **Outlet Valve – Closed**

- **Crankshaft Rotation – 180^0**

2. **Compression**: This stroke begins at B.D.C, or just at the end of the suction stroke, and ends at T.D.C. In this stroke the piston compresses the air-fuel mixture in preparation for ignition during the power stroke (below). Both the intake and exhaust valves are closed during this stage.

   Key points

   - **Inlet Valve – Closed**
   - **Outlet Valve – Closed**
   - **Crankshaft Rotation – 180^o (Total 360^o)**

3. **Combustion**: Also known as power or ignition. This is the start of the second revolution of the four stroke cycle. At this point the crankshaft has completed a full 360 degree revolution. While the piston is at T.D.C. (the end of the compression stroke) the compressed air-fuel mixture is ignited by a spark plug (in a gasoline engine) or by heat generated by high compression (diesel engines), forcefully returning the piston to B.D.C. This stroke produces mechanical work from the engine to turn the crankshaft.

   Key points

   - **Inlet Valve – Closed**
   - **Outlet Valve – Closed**
   - **Crankshaft Rotation – 180^o (Total 540^o)**

4. **Exhaust**: Also known as outlet. During the *exhaust* stroke, the piston, once again, returns from B.D.C. to T.D.C. while the exhaust valve is open. This action expels the spent air-fuel mixture through the exhaust valve.

   Key points
   - **Inlet Valve – Closed**
   - **Outlet Valve – Open**
   - **Crankshaft Rotation – 180^o (Total 720^o)**

Four-stroke engines are the most common internal combustion engine design for motorized land transport,[1] being used in automobiles, trucks, diesel trains, light aircraft and motorcycles. The major alternative design is the two-stroke cycle.[1]

Engine Control

Control of the engine in any car means regulating the power that it produces at any time in accordance with driving needs.

The driver controls engine power via the accelerator pedal, which, in turn, determines the setting of the throttle plate via a mechanical linkage system.

The throttle plate is situated in the air intake system (Figure). The intake system is an assembly of pipes or passageways through which the air flows from outside into each cylinder.

The air flowing into the engine flows past the throttle plate, which, in fact, controls the amount of air being drawn into the engine during each intake stroke.

The power produced by the engine depends on fuel being present in the correct proportions.

Air combines with fuel in the fuel metering device.

This device automatically delivers fuel in the correct amount as determined by the air flow.

The classic fuel metering device was the carburettor,

Ignition System

To produce power, the gasoline engine must not only have a correct mixture of fuel and air, but also some means of initiating combustion of the mixture.

• Essentially the only practical means is with an electric spark produced across the gap between a pair of electrodes of a spark plug.

• The electric arc or spark provides sufficient energy to cause combustion.

• This phenomenon is called ignition

The spark must persist for a period of about a millisecond

• The ignition system itself consists of several components:

1. the spark plug,

2. one or more pulse transformers (typically called

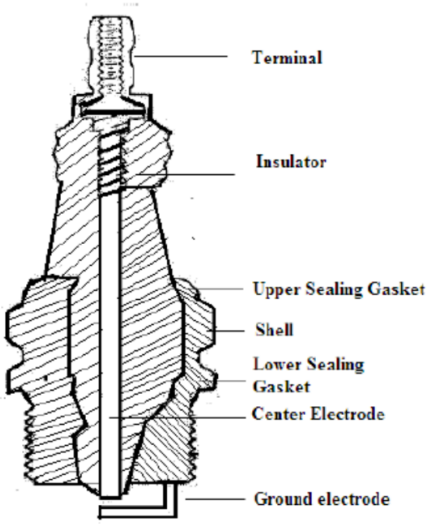
coils),

3. timing control circuitry,(ignition timing).

4. distribution apparatus that supplies the high-

voltage pulse to the correct cylinder

Spark plug

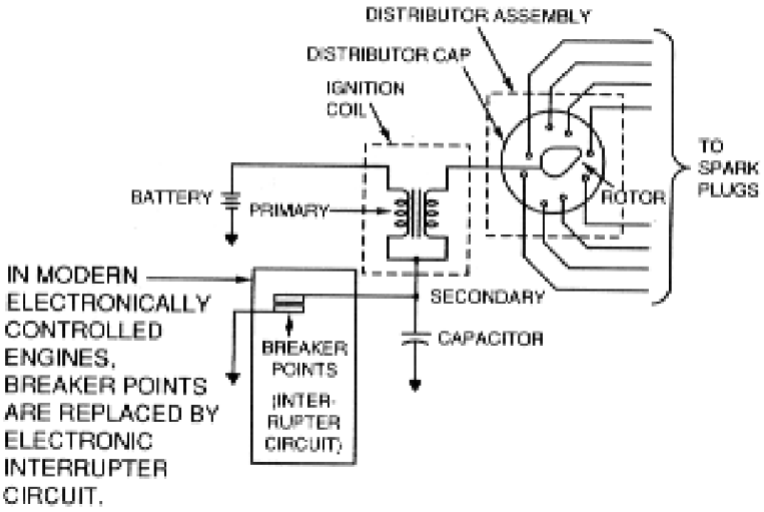


The spark is produced by applying a high- voltage pulse of from 20 kV to 40 kV between the centre electrode and ground.

• The actual voltage required to start the arcvaries with the size of the gap, the compression ratio, and the air–fuel ratio.

• The spark plug consists of a pair of electrodes, called the centre and ground electrodes, separated by a gap.

High voltage circuit and distribution



The high-voltage pulse is generated by inductivedischarge of a special high-voltage transformer commonly called an ignition coil.

• The distribution of high-voltage pulses was accomplished with a rotary switch called the distributor

• The centre electrode is mechanically driven by the camshaft (via gears) and rotates synchronously at camshaft speed (i.e., one-half of crankshaft speed).

Spark pulse generation

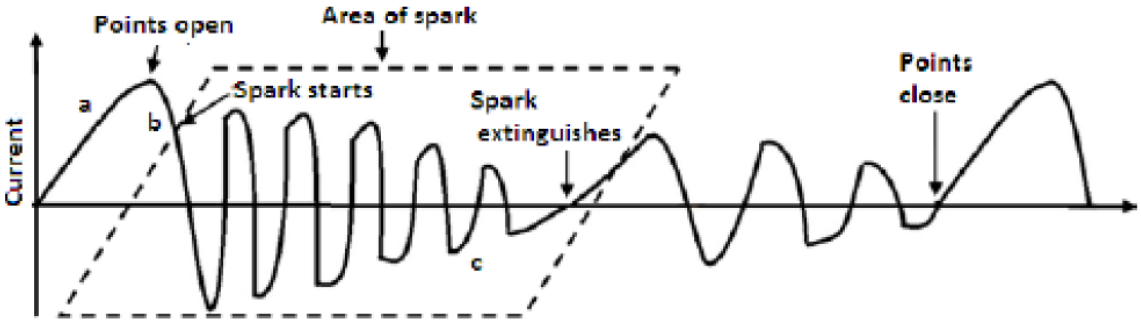


Fig.3 Primary Current Waveform

The actual generation of the high-voltage pulse isaccomplished by switching the current through

the primary circuit (see Figure).

• The mechanism in the distributor of a traditionalignition system for switching the primary circuit

of the coil consists of opening and closing thebreaker points (of a switch) by a rotary cam in the distributor (explained later).

• During the intervals between ignition pulses (i.e., when the rotor is between contacts), the breaker points are closed (known as dwell).

• Current flows through the primary of the coil, and a magnetic field is created that links the primary and secondary of the coil.

Ignition Timing

Ignition occurs some time before top dead centre (BTDC) during the compression stroke of the piston.

• This time is measured in degrees of crankshaft rotation BTDC.

• For a modern SI engine, this timing is typically 8 to 10 degrees for the basic mechanical setting with the engine running at low speed (low rpm).

This change in ignition timing is called spark advance.

• That is, spark advance should increase with increasing engine rpm.

• In a conventional ignition system, the mechanism for this is called a centrifugal spark advance.

• At the instant the spark pulse is required, the breaker points are opened.

• This interrupts the flow of current in the primary of the coil and the magnetic field collapses rapidly.

• The rapid collapse of the magnetic field induces the high voltage pulse in the secondary of the coil.

• This pulse is routed through the distributor rotor, the terminal in the distributor cap, and the spark plug wire to the appropriate spark plug.

• The capacitor absorbs the primary current, which continues to flow during the short interval in which the points are opening, and limits arcing at the breaker points.

Drive Train-

A **drivetrain** (also frequently spelled as **drive train** or sometimes **drive-train**) is the group of components that deliver mechanical power from the prime mover to the driven components. In automotive engineering, the drivetrain is the components of a motor vehicle that deliver power to the drive wheels. This excludes the engine or motor that generates the power

In contrast, the **powertrain** is considered to include both the engine and/or motor(s) as well as the drivetrain.

Drive Train consists of Engine, transmission, drive shaft, differential and driven wheels.

Transmission

• The transmission is a gear system that adjusts the ratio of engine speed to wheel speed.

• It provides a gear ratio between the engine speed and vehicle speed such that the engine provides adequate power to drive the vehicle at any speed.

• To accomplish this with a manual transmission, the driver selects the correct gear ratio from a set of possible gear ratios (usually three to five for passenger cars).

• An automatic transmission selects this gear ratio by means of an automatic control system.

• Most automatic transmissions have three forward gear ratios, although a few have two and some have four.

The proper gear ratio is actually computed in the electronic transmission control system.

• Automatic transmissions have three forward gear ratios, although a few have two and some have four.

Drive Shaft

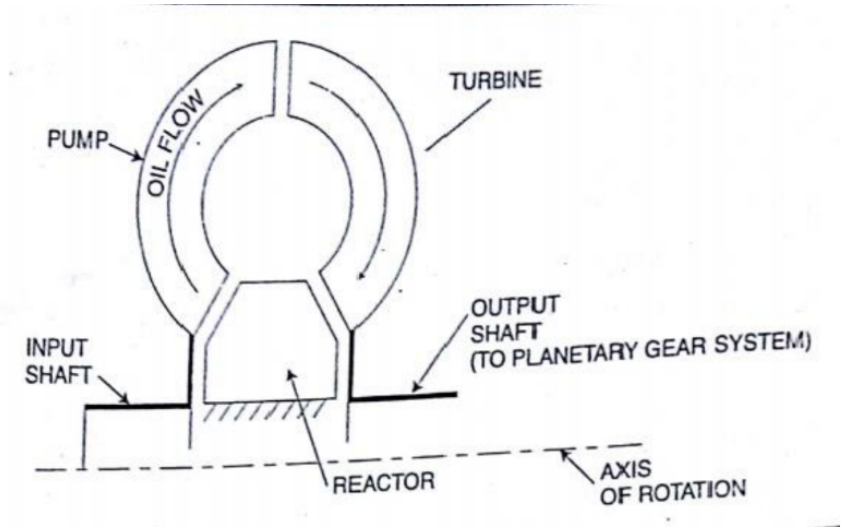
• It is used on front-engine, rear wheel drivevehicles to couple the transmission output shaft

to the differential input shaft.

• Flexible couplings, called universal joints, allowthe rear axle housing and wheels to move up anddown while the transmission remains stationary.

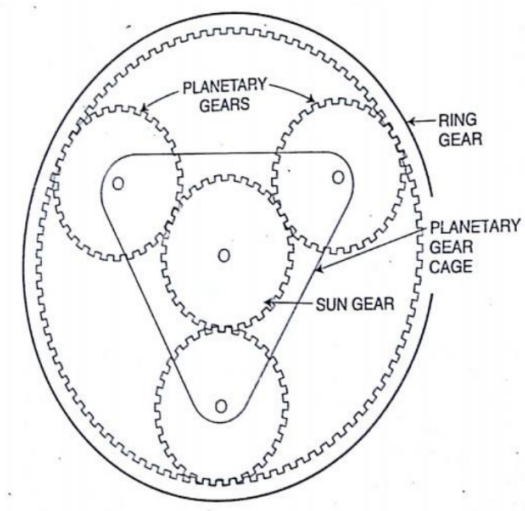
• In front wheel drive automobiles, a pair of drive shafts couples the transmission to the drive wheels through flexible joints known as constant velocity (CV) joints.

torque converter



To summarise, torque converter are used in automatic transmission for automatic decoupling between engine & transmission and also because of its torque multiplication advantage.

Planetary Gear System



A planetary gearbox is a gearbox with the input shaft and the output shaft aligned. A planetary gearbox is used to transfer the largest torque in the most compact form (known as torqe density).

• For a three-speed hub, a one-stage planetary gear system is used, for a five-speed hub a 2-stage. Each planet gear system has a reduction state, a direct coupling and an acceleration mode.

• In mathematical terms, the smallest reduction ratio is 3: 1, the largest is 10: 1. At a ratio of less than 3, the sun gear becomes too big against the planet gears. At a ratio greater than 10 the sun wheel becomes too small and the torque will drop. The ratios are usually absolute i.e. an integer number.

Differential

• It has three purposes;

• The most obvious is the right angle transfer of the rotary motion of the drive shaft to the wheels.

• The second purpose is to allow each driven wheel to turn at a different speed. This is necessary because the “outside” wheel must turn faster than the “inside’’ wheel when the vehicle is turning a corner.

• The third purpose is the torque increase provided by the gear ratio.

• In front wheel drive cars, the transmission differential and drive shafts are known collectively as the transaxle assembly.

SUSPENSION

• Is the mechanical assembly that connects each wheel to the car body.

• the wheel assembly is connected through a movable assembly to the body.

• The weight of the car is supported by springs. In addition, there is a so-called shock absorber which is in effect a viscous damping device.

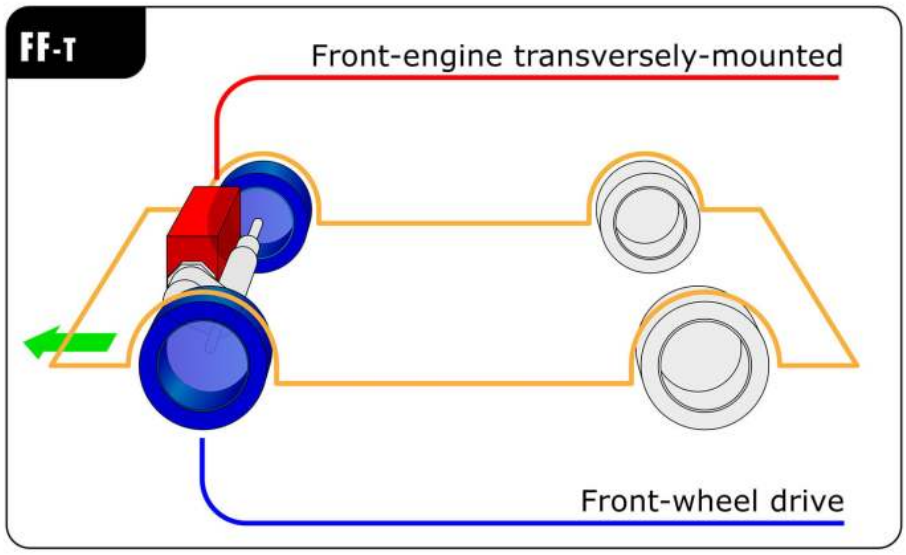
• The mass of the car body is called the sprung mass, that is, the mass that is supported by springs.

• The mass of the wheel assemblies at the other end of the springs is called unsprung mass.

The proportionality constant is known as the spring rate.

Types of Drive Train:

Front-Wheel Drive (FWD)



A car or truck with front-wheel drive has all of the engine's power being sent to the two front wheels, so the drivetrain is basically pulling the car down the road. This serves to give the car more traction, providing stability, predictability and dependability when the roads get a little icy. Examples of vehicles with FWD include the Toyota Camry and the Honda Accord.

Front Wheel Drive | Advantages

The front-wheel-drive configuration offers some advantages over Rear-wheel drive, as the gross weight of the car is set-up on the front, this, in turn, provides more traction to the front wheel which is being powered hence more grip on the road.

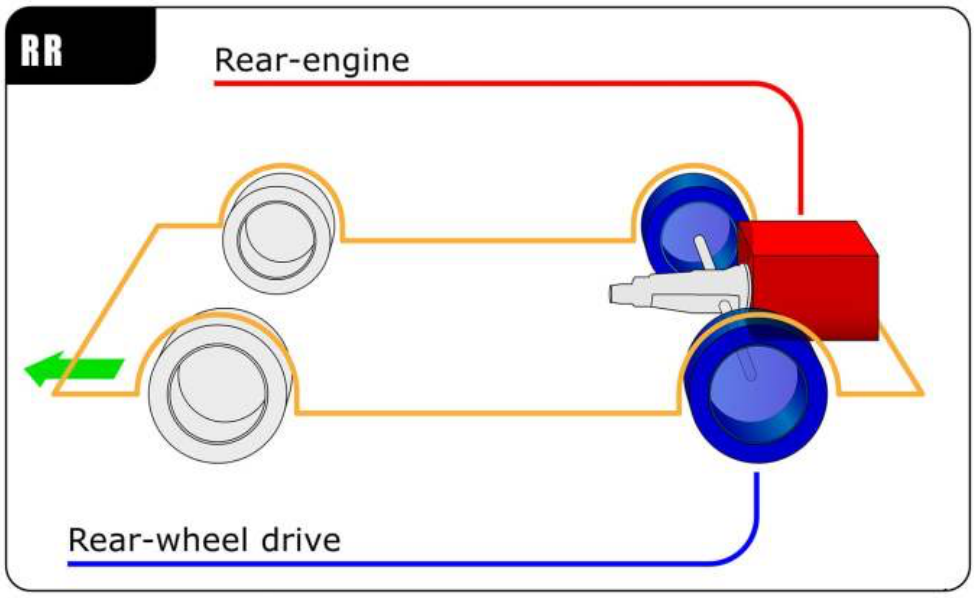
FWD also stands tall when it comes to manufacturing point of view as it's significantly cheaper to build and as getting popular day by day, it is only getting more cost-effective.
Front-Wheel Drive setup is also lighter and in turn, helps with the fuel economy. FWD is commonly deployed in city cars and economy hatches.

Front Wheel Drive | Disadvantages

There is a demerit for the popular FWD, which is known as Torque Steering. Due to the nature of the setup that burdens it with three tasks, FWD can suffer from some severe Torque Steering, which means that the power from the engine overwhelms the front wheels which is felt when the car undergoes hard acceleration and the steering goes haywire.

Torque Steering causes the vehicle to steer left or right on its own, under the influence of the torque transmitted from the engine. But with the ever-developing modern technology, FWDs are getting smarter and agiler.

Rear Wheel Drive (RWD)



With rear-wheel drive, all of the engine's power is sent to the back two wheels. Opposite of cars with FWD, a car with RWD is being pushed down the road. This does not work well in areas with icy winters because the level of traction is low. Despite this, RWD provides balance and offers superior braking and handling. Examples of vehicles with RWD include the Lexus IS Series and the BMW 3 Series.

Rear Wheel Drive | Advantages

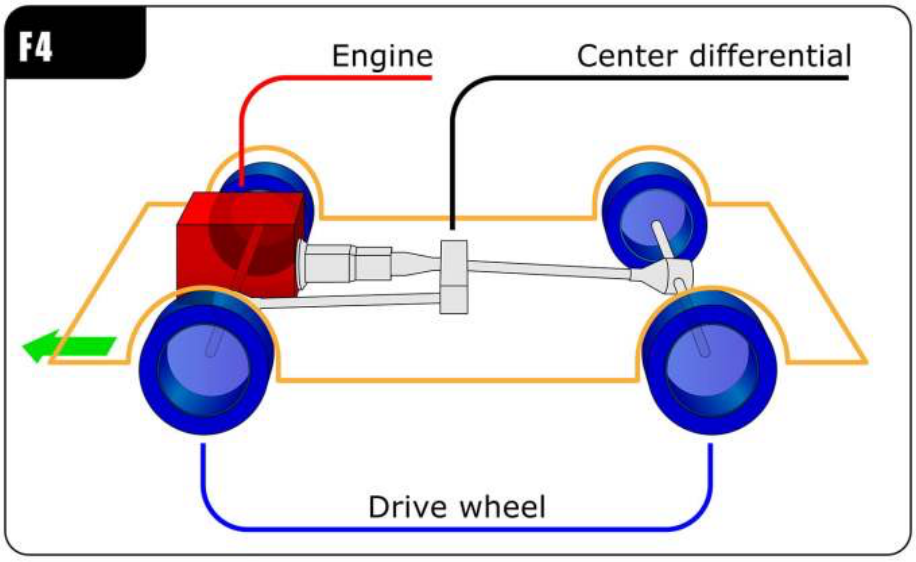
RWD does wonders for the car and if you observe there is a perfect symphony between the front and the rear wheels as the rear pushes and the front steers hence there is no Torque Steering which allows for a more engaged and dynamic driving experience, therefore, RWD can handle more horsepower compared to an FWD.

This also provides engineering to tweak the suspension and the overall vehicle configuration. RWD is commonly employed in SUVs, premium luxury sedans and sports cars.

Rear Wheel Drive | Disadvantages

There are issues with the RWD though. It provides less traction when it encounters slippery and tread-unfriendly road surfaces. RWD is also relatively expensive to manufacture and service.

All Wheel Drive (AWD)



The all-wheel drivetrain system has fluid-filled differentials and advanced electronics enabling the engine to send power to all four wheels. This provides a vast and highly improved capability for

driving on wet or slippery roads. Examples of vehicles with AWD include the Subaru Legacy and the Acura RL.

All Wheel Drive | Advantages

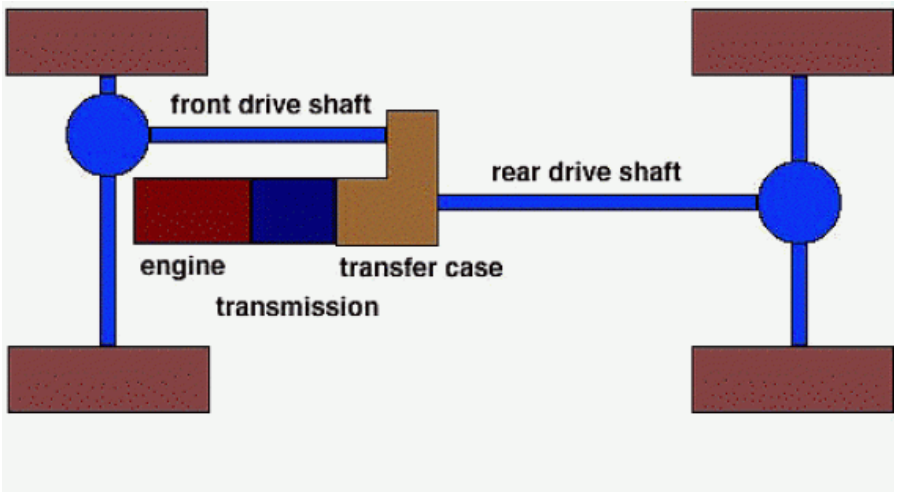
Depending on the system, in an AWD, power can be efficiently regulated and channelised to provide optimal traction at all time. In most systems, the power is sent to the front wheels in an instance of hard acceleration, and to the rear, in case better cornering stability is required. AWD also utilises the assistance of Traction Control which helps in attaining optimal driving rigidity.

AWD systems are especially helpful in rapidly changing road conditions. A **transfer junction** located at the middle of the car is responsible for diverting power to every wheel as it sees fit. Audi's very own **QUATTRO** is an exceptional variant of the AWD drivetrain.

All Wheel Drive | Disadvantages

Demerits of AWD lies in the complexity of its manufacturing process. AWDs are also costly to repair and service.

4 Wheel Drive (4WD)



On the spec sheet, AWD and 4WD appear the same, and at any time both these terms are used interchangeably. Both these configurations utilise all the four wheels for traction. 4WD is also known as 4X4.

The very fundamental difference between these two lies in the flexibility that a 4WD offers. The 4WD is for more enthusiastic driving. It allows the driver to tweak the details of the vehicle's driving attributes giving a more involved experience, that is why 4WD is primarily featured on purpose-built SUVs and off-roaders that require on the go drivability for severe off-roading, boulder climbing, water wading, steep hills, low traction demands.

4 Wheel Drive | Advantages

Most 4WD vehicles have a high and a low gear range; the latter is used to increase low-speed climbing power. Some have differentials (which allow left and right wheels and front and rear axles to turn at different speeds) to be locked for maximum traction. Most 4WD function via a second gear shift or through a button in the case of modern vehicles.

The 4WD is considered the holy grail amongst the serious off-roading community courtesy it tweakable driving characteristics.

4 Wheel Drive | Disadvantages

Aside from this. 4WD has no actual benefits in a typical day to day driving and being very similar to AWD, 4WD is also on the expensive side when it comes to service and repair.

Brakes

Brakes are as basic to the automobile as the engine drive train system and are responsible for slowing and stopping the vehicle.

• Most of the kinetic energy of the car is dissipated by the brakes during deceleration and stopping

Two major types of conventional automotive brakes: drum and disc brakes.

• Drum brakes are an extension of the type of brakes used on early cars and horse drawn wagons.

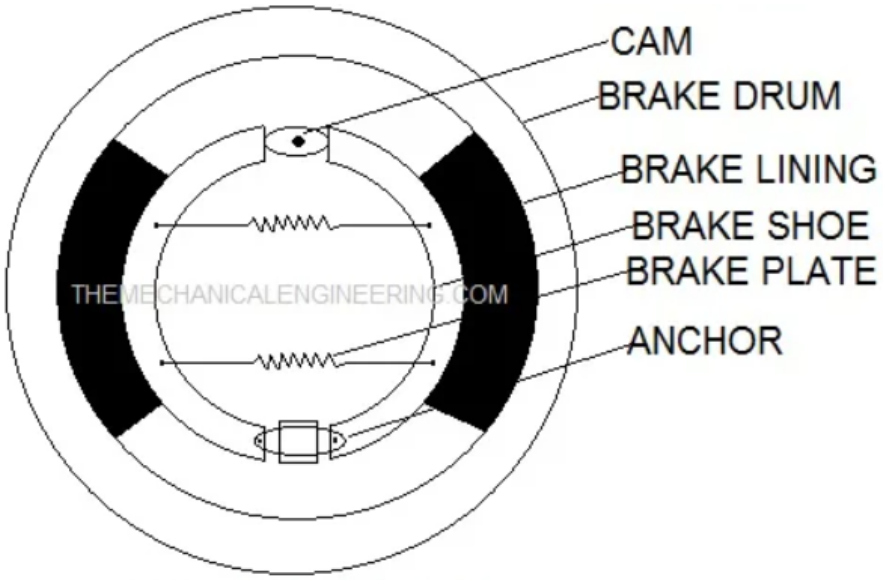
• Increasingly, automobile manufacturers are using disk brakes.

1. Mechanical Brake System:

This mechanical braking system is the hand brake or the emergency brake, it generates friction between two surfaces as they rub against each other.

In this braking system, a particular force is applied to the pedal and it's carried to the final drum by mechanical components such as a fulcrum, springs, and that are used as linkages to transmit force from one point to another, for slowing down the vehicle.

The slowing down of the speed or capacity of a brake depends on the surface friction as well the actuation force applied to it.



MECHANICAL BRAKE

Advantages of Mechanical Braking System:

- Mechanical brakes are simpler and easy to be maintained.
- It is less expensive than a hydraulic brake system.
- It provides great uses for emergency and parking brakes.

2. Hydraulic Braking System:

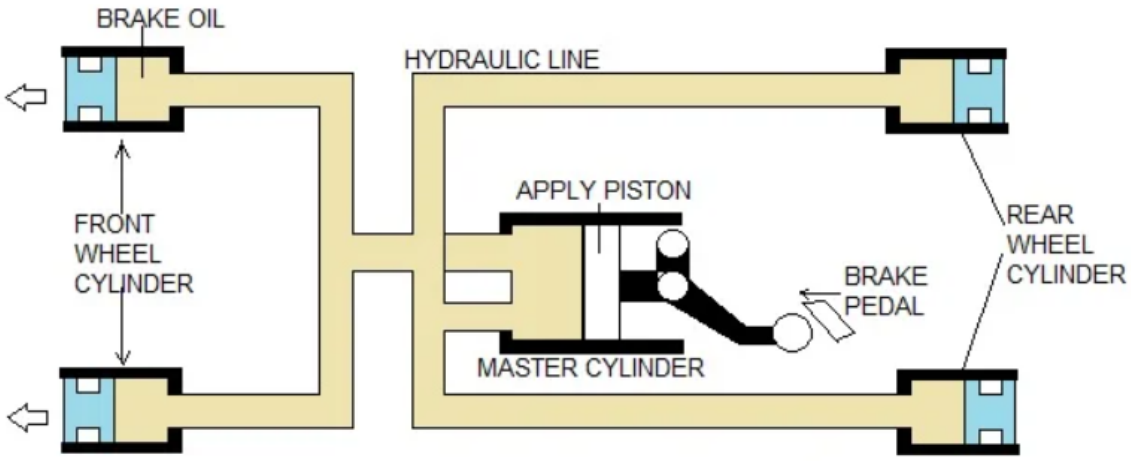
A magnetic flux is passed in a direction perpendicular to the rotating direction of the particular wheel, a rapid current flowing in a direction opposite to the rotation of the wheel creating an opposing force to the wheel rotation thus, gradually slowing down the wheel speed.

It transmits the brake system to the wheels of the brake through the pressure of fluids, converting the pressure into useful work of wheel brakes.

The Brake pedal relays the driver foot effort to the master cylinder piston, which compresses the brake fluid.

The fluid pressure is the same as it's transmitted to the front disc-caliper pistons and the rear disc caliper pistons. As per the process, a different mechanical parking brake must be included with at least two wheels.

This also allows the driver to be in control of the vehicle in the cause of a failure with the Hydraulic Brake system.



HYDRAULIC BRAKE SYSTEM LINE DIAGRAM

Advantages of Hydraulic brake system

The Hydraulics offers the following advantages over the mechanical layout:

- It provides equal braking effort on all wheels.
- Relative brake effort is less to deliver the same output.
- It is full compensated thus each brake receive a full share of pedal effort
- It is more efficient than mechanical.
- Suitable for all types of vehicles having independent suspension.

3. Pneumatic Braking System:

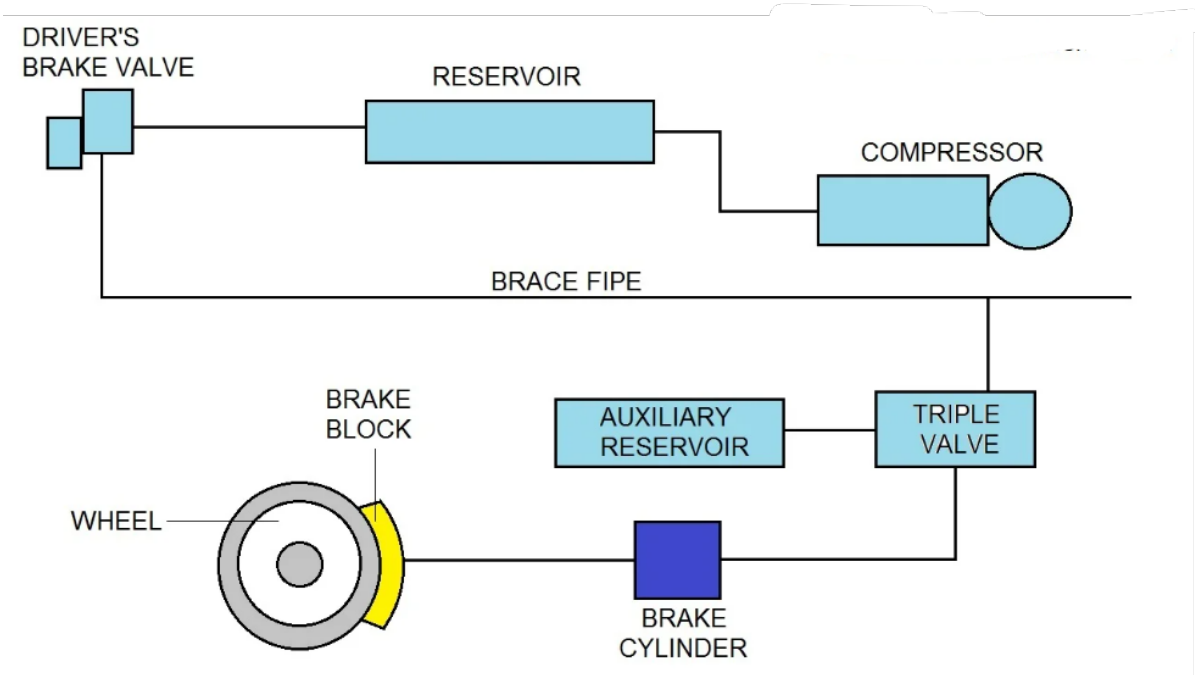
It maintains a higher level of pressure inside it, and the pressure in line starts dropping the moment when the driver applies the brake causing a result in slowing down the vehicle trucks buses and trains use this type of braking system.

It operates on compressed air helps in charging up the entire braking system to maintain optimum pressure.

The charged-up lines make sure for the brakes to be dis-engaged, the very moment the driver applies the force onto the pedal the air pressure drops.

Due to this sudden drop of pressure, the control reservoir, and gets disconnected causing the auxiliary cylinder to be connected to the brake cylinder.

Compressed air from the auxiliary cylinder gets to the brake cylinder causing it to be more engaged. This is how the pneumatic brake works.



Advantages of a pneumatic brake system:

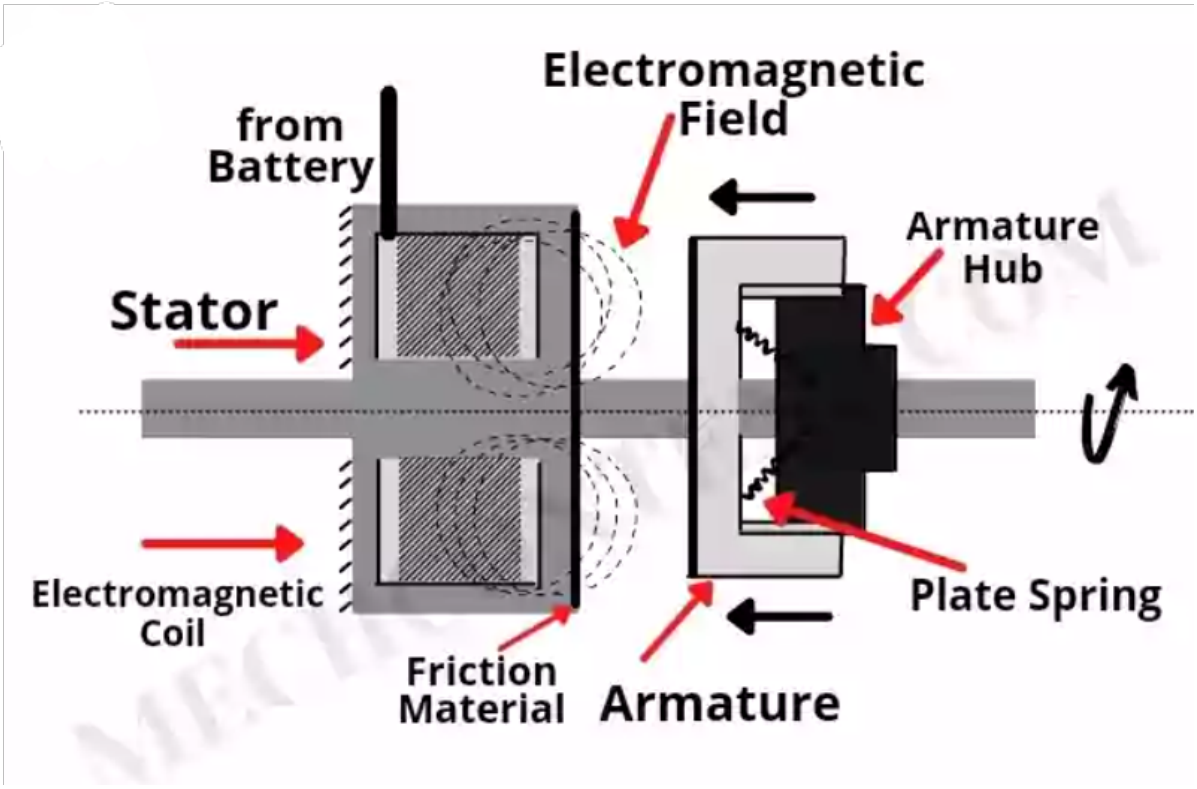
- Pneumatic brake equipment is much more reliable than hydraulic brakes
- If there is a leakage in the pneumatic brake system, there is less wastage as compared to leakage in the hydraulic brake system.
- It is very powerful with a single pedal that can work the entire pneumatic brake equipment which makes everything easy to control and there are fewer chances of mistakes.
- Their systems are clean as the compressed air used in the operation can be directly dumped into the atmosphere.

4. Electromagnetic Break System:

The electromagnetic system can be used in both modern and hybrid vehicles. The principles of electromagnetism are to achieve frictionless braking.

It increases the lifespan and reliability of the brakes also it's backed by quick magnetic brakes so without the use of friction or any lubrication this technology is preferred in hybrids as they are moderate in size compared to the normal braking. It is mostly used in trams and rails.

A magnetic flux is passed in a direction perpendicular to the direction of the rotating particular wheel, a rapid current flowing in a direction opposite to the rotation of the wheel creating an opposing force to the wheel rotation which hence reduces and slows down the speed



Advantages of an electromagnetic field:

- Brake is faster and cheaper.
- There is no replaceable cost for brake shoes periodically.
- This breaking helps in increasing the capacity of the system.
- In this braking, a small amount of heat is generated wherein in mechanical braking an enormous amount of heat is generated.
- A part of the energy is delivered to the supply consequently the running cost is reduced.

5. Servo Braking System:

It is also known as vacuum-assisted braking. In this process, the pressure applied to the pedal by the driver is increased.

It uses the vacuum that is produced inside the petrol engines by the air intake system also it uses the power assistance to reduce the manpower effort.

Servo braking system boosters used with the hydraulic brake system increase the braking force applied on the surface, pushing the brake pedal to release the vacuum on the side of the booster the difference in the air pressure makes the diaphragm in slowing down.

Lets Have a look At the Advantages of Servo Braking:

- It is Simpler in design.
- It provides greater level of safety because a loss in volume result in the breaking of the vehicle.

- More reliable in rail wagons.
- It's simpler to control as it permits the automatic process of the brake down the entire length of the train by applying a decent force.
- It is more effective as its ability to get partial release it's something that the pneumatic brake could not do without adding an additional equipment.

6. Electrical braking system:

It is mainly used in electric vehicles in which braking is produced using electric motors, and it's the main power source in electric vehicles. It basically categorized into three types.

6.1 Plugging or Counter current Braking:

It is the simpler form of braking runs when gets connected to motor windings for the reverse direction of rotation at a particular time when the armature still rotates in the forward direction under control of the action of an external torque or due to inertia.

Plugging reconnects the power source with the motor, so it moves to drive in the opposite direction. It is generally obvious for the system to come at rest as it's mostly required and then to accelerate in the reverse direction.

It is important to introduce a special device and to cut off the supply exactly at the time when the motor stops.

This method produces a greater braking torque. It's beneficial to get a quick reversal or to get a more rapid stop in an event of the control.

It is mostly used in rolling mills, elevators, machine tools, etc. This method can be used in both direct current and alternating current and also in induction and synchronous motors.

6.2 Dynamic Braking system:

In this particular method, the motor power is cut from the supply and it operates as a generator carried by the kinetic energy of the rotating parts of the motor and its driven machines.

Thus, the kinetic energy gets converted into the electrical energy of the rotation.

Which is then dissipated and connected at the breaking instant. Using this method, the exact amount of energy required for the power supply to break the motor has been removed as compared to the plugging method.

And this is one of the advantages of dynamic Braking: It applies to direct current motors, synchronous motors, and induction motors.

6.3 Regenerative Braking:

In this method, the mechanical energy is converted into electrical energy. Some parts of energy are returned to the supply and the rest of the energy is lost as heat in the windings and bearings

of the electrical machines. It did not involve any switching method unless a change of speed is required at which it becomes more efficient.

Most of the widely electrical machines pass smoothly from motoring to operations generating, when getting overdriven by the load.

Necessities For Regenerative Brake System:

- Lesser Supply voltage.
- The motor to be a little more excited.
- The motor to be running at a higher speed than no-load speed.

In all of this process, the retarding torque is produced and the armature current is reversed, decreasing the speed of the motor until the armature back emf becomes the same as a voltage source.

Regenerative braking does not stop the motor. It is only efficient for handing braking hauling loads, they also vehicle increased the motor due to the work of lowering load or in the motor of an electric locomotive moving downgrade.

Advantages of Electric Braking:

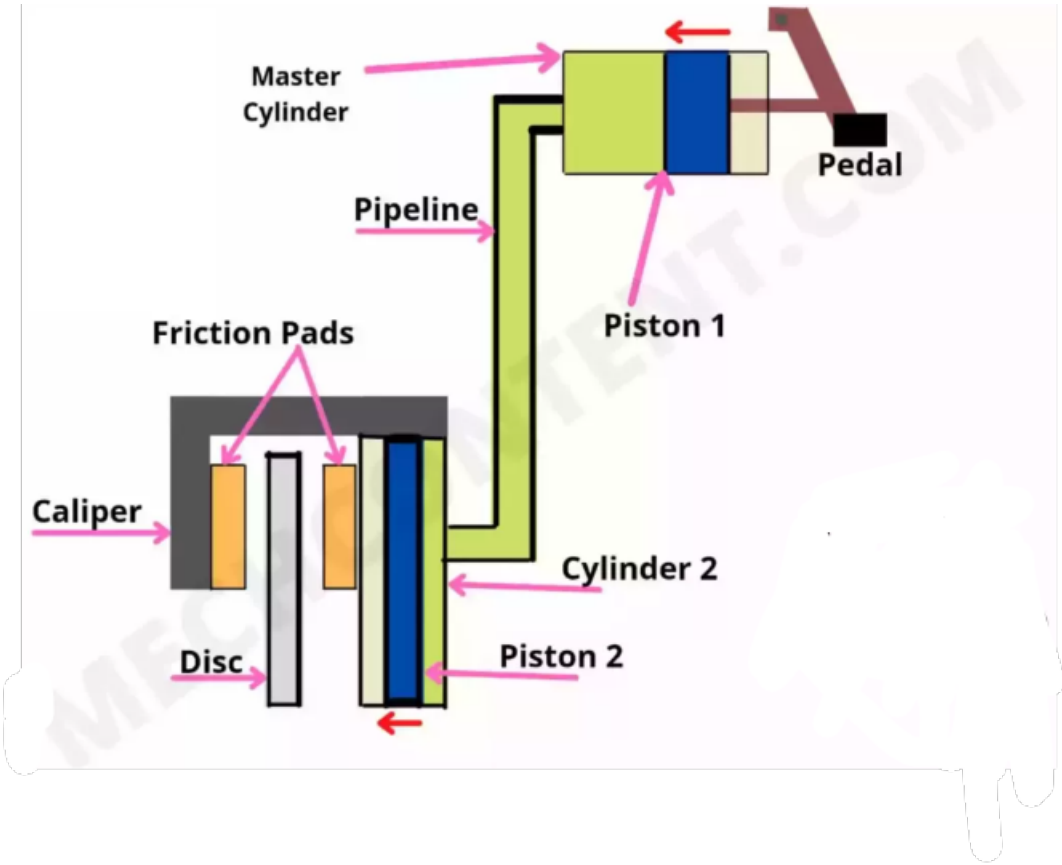
- It's more efficient than the mechanical braking system which needs costly and frequent replacement but no such replacement is required in electric braking hence it's cheaper and works efficiently.
- By using of electric braking, speed capacity of the system increases way higher with haulage of heavy loads.
- It helps in saving energy, as a small amount of energy returns to supply offering a considerable saving in the operating cost.
- Metal dust is produced in mechanical braking, but no such dust is produced in electric placement of the mechanical brakes may result in harsh effects in the discomfort to occupants. On the other side electric braking is way more safer, smoother and without shock.

7. Disc Brake System:

Brake Fluid is compressed by a piston inside the master cylinder located at the base of the vehicle hood beside the engine, thus creating a huge amount of hydraulic pressure, also producing a large amount of force just by pressing the pedal down.

The pressure gets passed via the brake fluid and then to brake horses that connect a linkage with the brake assembled at each wheel.

The conversion of wheel pressure takes place with the hydraulic force to be converted to the mechanical force causing the brake friction to push against the disc, and the drum helps to decrease the speed and stop it completely.



7.1 The floating caliper:

It is the most common type used with one or two pistons, when the brakes are applied, the inner brake pad gets rest against the disc while at the exact time the caliper body shifts closer to the router.

This process forces the outer brake pad against the router.

7.2 The fixed caliper:

Its piston is mounted on each side of the router. The caliper does not bulge out, it is rigidly fastened to the spindle. When applying brakes, the caliper piston shifts, pressing the brake pads against the disc.

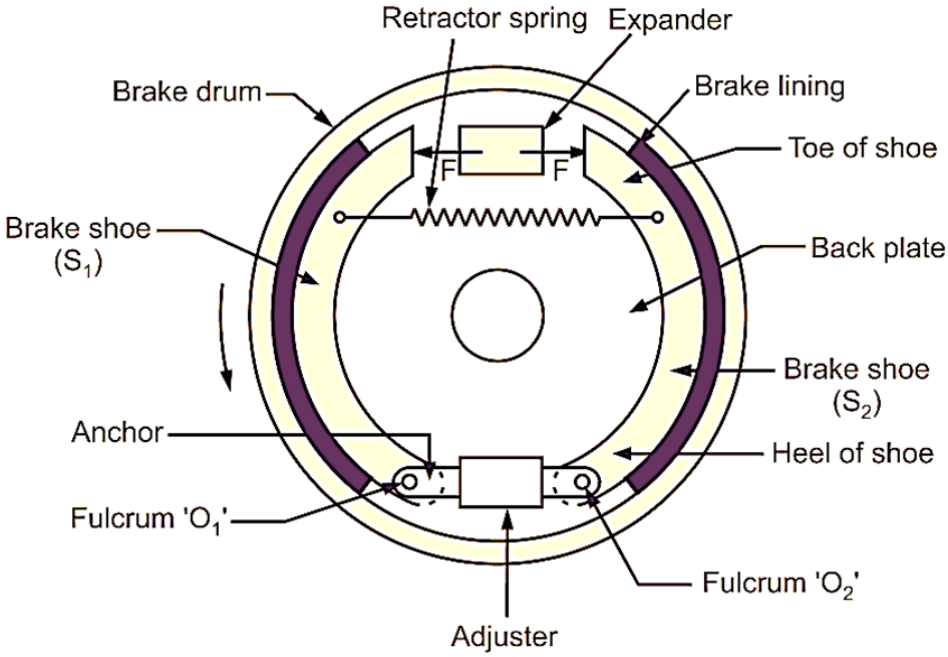
Advantages of Disc brake System

- It produces more force-stopping power.
- More efficient to apply for a shorter stopping distance.
- Provides a self-cleaning facility.
- This is more durable and lighter.

8. Drum Braking System:

It is the brake type in which a drum which is mainly used for the brake shoes along with its real mechanism is attached to the hub of the wheel in such a way the inner parts remain constant and the outer part of the drum rotates with the wheel.

When brakes are applied, the mechanical linkages cause the brake shoes to expand a little due to which the outward friction surface of the brake shoes gets in frictional contact with the rotating drum part which helps in stopping or de-accelerating the wheels.



Advantages Of Drum Brake System

- It generates less heat since most of the stopping force is generated by the front brakes of the vehicle.
- It produces or emits less particulate matter than disc brakes.
- Its frictional contact area is at the circumference hence it provides more braking force than an equal diameter disc brake.
- It got a low level of maintenance to improve corrosion resistance compared to the disc.
- It is less expensive and reliable.

9. Emergency Brake System:

They are also known as parking brakes, it acts as secondary and independent braking System for all the service brakes.

There are several kinds of emergency brake (a level between the driver placed, a third pedal, a handle beside the steering column, etc.)

They are all sourced by cables that apply the pressure mechanically to the wheels, generally maintain the vehicle stationary when parked, and are used in emergency situations if the stationary brakes are not at work.

10. Anti-lock Braking system:

Most of the modern vehicles are introduced to anti-lock Braking systems. They are installed for good as the reasons for several advantages mostly having to do with the driver and passenger safety.

For beginners, anti-lock brakes allow drivers to maintain control of their vehicles with all types of road conditions.

It provides rushing stopping at the exact point where the driver wants, without using these brake roads with slippery conditions can turn out a bit risky.

One of its great advantages is that its system parts work together, for instance, ABS controls wheel activity with the sensor placed on both wheels. The sensor is controlled by the brake force ensuring the wheel's speed to run in tandem.

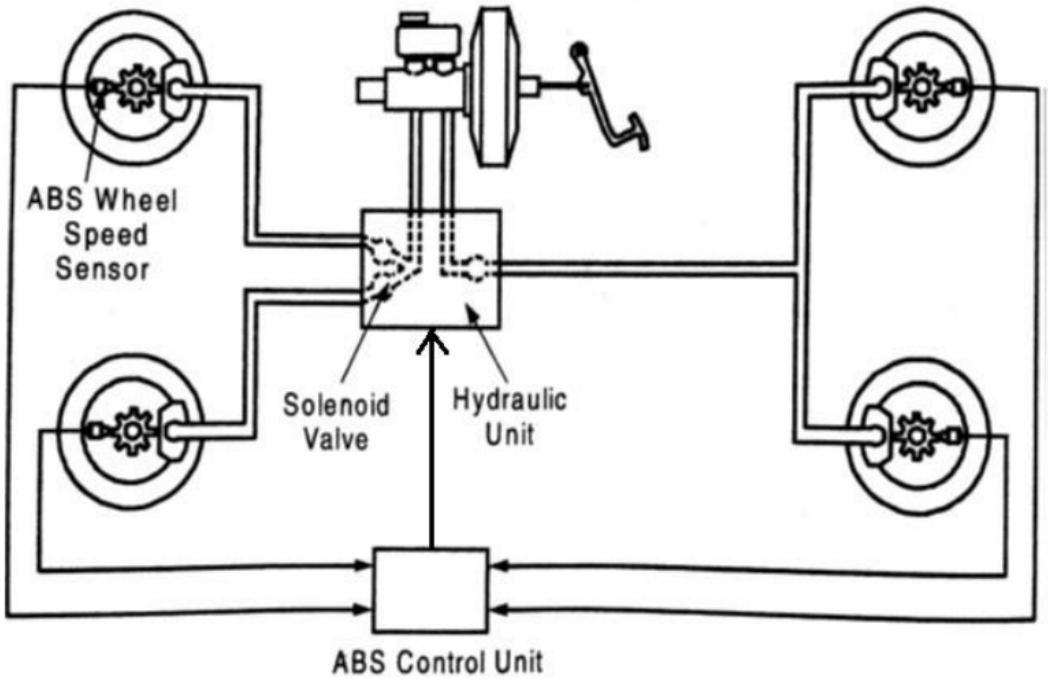


Fig. 5.19. Antilock Braking System

Steering System

8.1. PURPOSE OF A STEERING SYSTEM

The **steering system** *allows the driver to guide the car along the road and turn left or right as desired.*

The system includes the following :

(*i*) *The steering wheel* ..... which the driver controls.

(*ii*) *The steering gear* ..... which changes the rotary motion of the wheel into straight line motion, and

(*iii*) *The steering linkages* ..... which transmit the steering gear movement to the front wheels.

- The steering system configuration depends on vehicle design (the drive train and suspension system used, whether it is a passenger car or a commercial vehicle etc.). At present, the rack-and-pinion type and the recirculating-ball types are in use.
- Most steering systems were *manual* until a few year back. Then *power steering* became popular. It is now installed on almost all costly cars.

8.2. FUNCTIONS OF A STEERING SYSTEM

Following are the *functions* of a steering system :

1. The primary function of the steering system is *to achieve angular motion of the front wheels to negotiate a turn.*
2. To provide directional stability of the vehicle when going straight ahead.
3. To facilitate straight ahead recovery after completing a turn.
4. To minimise wear and tear of tyres.
5. To absorb a major part of the road shocks thereby preventing them to get transmitted to the hands of the driver.
6. To provide perfect rolling motion of the road wheels at all times.

The *main parts of a steering system* are :

1. Steering wheel.
2. Steering column.
3. Steering shaft.
4. Steering gear box.
5. Steering drop arm (Pitman arm).
6. Pull and push rod (Drag link).
7. Knuckle arm.
8. Tie rod and tie rod end.

Working of steering mechanism :

- The *steering wheel* rotates the *steering column*. The *steering gear box* is fitted to the end of this column. Therefore, when the wheel is rotated, the *cross shaft* in the gear box oscillates. The cross shaft is connected to the *drop arm*. This arm is linked by means of a *drag link* to the *steering arms*. The steering arms on both wheels are connected by the *tie rods* to the drag link.
- When the steering wheel is operated, the knuckle moves to and fro, moving the wheels to the right or left. The ends of the tie rod and steering knuckle are connected to each other. One end of the drag link is connected to the tie rod. The other end is connected to the end of the drop arm. A ball and a socket joint gives the required movement to the joints between the tie rod, drag link and drop arm. When the vehicle is moving, the drop arm develops vibration. Shock springs are used in ball and socket system to absorb this vibration.

Brief description of steering parts :

1. ***Steering wheel :***
   - It is made of steel ring welded together on a hub with the help of two, three or four spokes. After welding ring with the spokes is ebonite moulded on it.
     - — In certain vehicles centre hub has splines cut on it while in other cases a key groove is given to secure the steering shaft firmly in it.
   - The steering wheels, in over country, have a *fixed position*. However, in foreign countries, these wheels in some vehicles can be *tilted and located in position* to suit the driver.
   - Steering wheel is pulled out with the help of a *puller*.
2. ***Steering outer tube or steering column :***
   - This is a hollow steel pipe in which steering shaft is housed.
   - One end of the pipe is fixed on steering box, the other end is usually held with the help of bracket under the instrument panel.
3. ***Steering shaft :***
   - The steering shaft is made out of good quality steel.
   - One end is fixed in the steering wheel with the help of splines or key and kept tight by nut. The other end with worm is secured firmly in the steering box with the help of bearing placed both on top and bottom. Sometimes, instead of one shaft, two pieces of shafts are also used (in those cases where steering wheel and steering box are not in one line)
4. ***Steering gear box :***
   - Its function is to *convert rotary motion of wheel into to- and-fro motion of drop arm* so that the drag link tied up with drop arm can be pushed or pulled resulting into moving stub axle to right or left as desired by the driver.
5. ***Drop arm :***
   - It is forged out of good quality steel.
   - Its one side is provided with splines which match the splines of sector shaft and held on sector shaft by nut. The other end has taper hole in which ball end is held tight with the help of nut.

Battery

The starter battery is an electrochemical storagefacility for the excess electrical energy that is generated by the alternator while the engine isrunning.

• This stored energy is needed during vehicle operationin the phases when the energy required by the active consumers is greater than the energy that is generated by the alternator

Function and requirements:

• The starter battery is the electrical energy storage facility in the vehicle electrical system.

It has the following tasks:

▶️Provide electrical energy for the starter

▶️Compensate for the deficit between generation andconsumption if the vehicle electrical system is not being supplied with an adequate amount of energy by the alternator (e.g. at idle speed or if the engine is stopped)

▶️Damping of voltage peaks from the vehicle system voltage to protect sensitive electronic and electrical components

Starter batteries can be subdivided into two types:

▶️Closed batteries:

• These are batteries with freely moving electrolytes in which any gas that builds up can escape through holes in the cover. The vast majority of all starter batteries are closed batteries.

▶️Sealed batteries:

• These batteries only allow gas to escape if the pressure in the battery exceeds a certain value. The battery cannot be topped up with sulfuric acid. The electrolyte is fixed, i.e. it is not freemoving.

With regard to maintenance, starter batteries are categorized into;

▶️ Conventional and low-maintenance batteries

▶️ Maintenance-free batteries

Starting System

Components of starting system

1. Battery

The automotive battery, also known as a lead-acid storage battery, is an electrochemical device that produces voltage and delivers current. In an automotive battery we can reverse the electrochemical action, thereby recharging the battery, which will then give us many years of service. The purpose of the battery is to supply current to the starter motor, provide current to the ignition system while cranking, to supply additional current when the demand is higher than the alternator can supply and to act as an electrical reservoir.

2. Ignition Switch

The ignition switch allows the driver to distribute electrical current to where it is needed.

There are generally 5 key switch positions that are used:

1. Lock- All circuits are open (no current supplied) and the steering wheel is in the lock position. In some cars, the transmission lever cannot be moved in this position. If the steering wheel is applying pressure to the locking mechanism, the key might be hard to turn. If you do experience this type of condition, try moving the steering wheel to remove the pressure as you turn the key.
2. Off- All circuits are open, but the steering wheel can be turned and the key cannot be extracted.
3. Run- All circuits, except the starter circuit, are closed (current is allowed to pass through). Current is supplied to all but the starter circuit.
4. Start- Power is supplied to the ignition circuit and the starter motor only. That is why the radio stops playing in the start position. This position of the ignition switch is spring loaded so that the starter is not engaged while the engine is running. This position is used momentarily, just to activate the starter.
5. Accessory- Power is supplied to all but the ignition and starter circuit. This allows you to play the radio, work the power windows, etc. while the engine is not running.

Most ignition switches are mounted on the steering column. Some switches are actually two separate parts;

* The lock into which you insert the key. This component also contains the mechanism to lock the steering wheel and shifter.
* The switch which contains the actual electrical circuits. It is usually mounted on top of the steering column just behind the dash and is connected to the lock by a linkage or rod.

3. Neutral Safety Switch

This switch opens (denies current to) the starter circuit when the transmission is in any gear but Neutral or Park on automatic transmissions. This switch is normally connected to the transmission linkage or directly on the transmission. Most cars utilize this same switch to apply current to the back up lights when the transmission is put in reverse. Standard transmission cars will connect this switch to the clutch pedal so that the starter will not engage unless the clutch pedal is depressed. If you find that you have to move the shifter away from park or neutral to get the car to start, it usually means that this switch needs adjustment. If your car has an automatic parking brake release, the neutral safety switch will control that function also.

4. Starter Relay

A relay is a device that allows a small amount of electrical current to control a large amount of current. An automobile starter uses a large amount of current (250+ amps) to start an engine. If we were to allow that much current to go through the ignition switch, we would not only need a very large switch, but all the wires would have to be the size of battery cables (not very practical). A starter relay is installed in series between the battery and the starter. Some cars use a starter solenoid to accomplish the same purpose of allowing a small amount of current from the ignition switch to control a high current flow from the battery

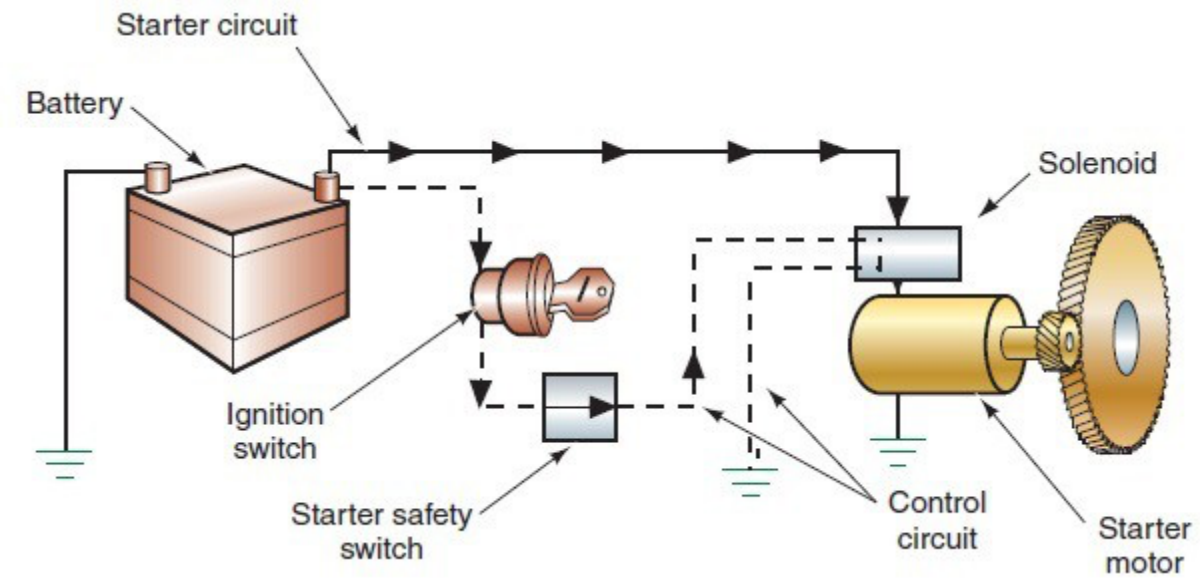
to the starter. The starter solenoid in some cases also mechanically engages the starter gear with the engine.

5. Battery Cables

Battery cables are large diameter, multistranded wire which carry the high current (250+ amps) necessary to operate the starter motor. Some have a smaller wire soldered to the terminal which is used to either operate a smaller device or to provide an additional ground. When the smaller cable burns, this indicates a high resistance in the heavy cable. Care must be taken to keep the battery cable ends (terminals) clean and tight. Battery cables can be replaced with ones that are slightly larger but never smaller.

6. Starter Motor

The starter motor is a powerful electric motor, with a small gear (pinion) attached to the end. When activated, the gear is meshed with a larger gear (ring), which is attached to the engine. The starter motor then spins the engine over so that the piston can draw in a fuel/ air mixture, which is then ignited to start the engine. When the engine starts to spin faster than the starter, a device called an overrunning clutch (bendix drive) automatically disengages the starter gear from the engine gear.



Working principles.

The starting system includes the battery, starter motor, solenoid, ignition switch and in some cases, a starter relay. An inhibitor or a neutral safety switch is included in the starting system circuit to prevent the vehicle from being started while in gear. When the ignition key is turned to the start position, current flows and energizes the starter's solenoid coil. The energized coil becomes an electromagnet which pulls the plunger into the coil. The plunger closes a set of contacts which allow high current to reach the starter motor.

In a petrol engine (gasoline engine), the combustible mixture of air and petrol is prepared outside the cylinder.

• A petrol engine needs a richer mixture while starting and a leaner (weaker) mixture while normal running.

• Such requirements of a petrol engine must be fulfilled before the charge (air-fuel mixture) enters the cylinder.

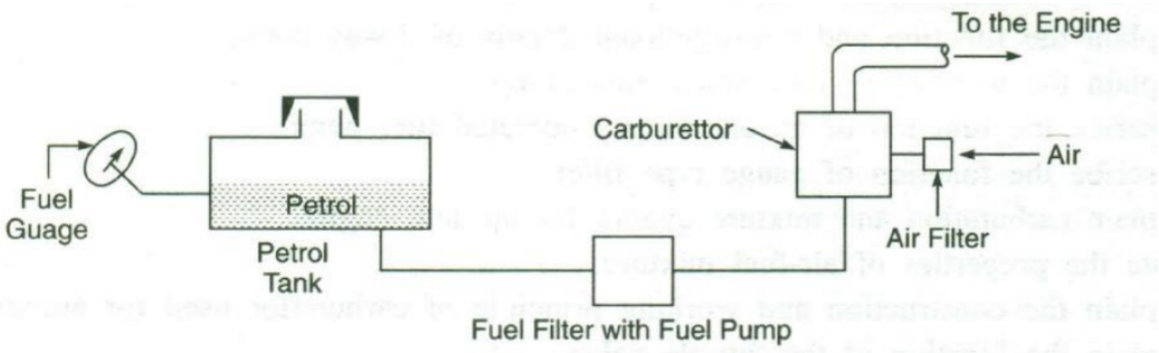


Fig. 7.1 Layout of Fuel System

Fuel Tank: Petrol is stored in a tank

• Fuel gauge: To indicate quantity of petrol available in the fuel tank. [battery-operated, Placed away from the fuel tank]

• Fuel Pump & filter: Either operated mechanically or electrically. It maintains constant petrol pressure in the float chamber attached to a carburettor.

• Fresh air from the atmosphere enters the carburettor where air mixes with fuel and forms a combustible mixture.

• The air filter traps or arrests dust particles which are suspended in atmospheric air.when the fuel tank is full with petrol, pressure on the float is greater than the pressure when the tank is not full.

• float valve is pushed down with greater force and more fuel (petrol) enters the float chamber.

When the fuel tank is full with petrol, the carburettor supplies richer mixture and, it supplies leaner mixture when reserved petrol is left in the fuel tank.

Fuel Injection

Fuel is supplied through hot compressed air in the combustion chamber

• The liquid fuel has to absorb heat for evaporation and find air for combustion in short duration of time.

• To meet these requirements, the fuel has to be atomized into fine particles so that the heat-absorbing area is increased for immediate evaporation.

Requirements

• To spray the correct quantity of fuel as required, depending on the load.

• To inject the fuel at the correct time in the cycle.

• To inject the quantity of fuel at such rate that constant pressure combustion is obtained.

• The sprayed fuel must be atomized such that the fuel gets depression and penetration.

• Starting and ending of injection must be sharp without dribbling.

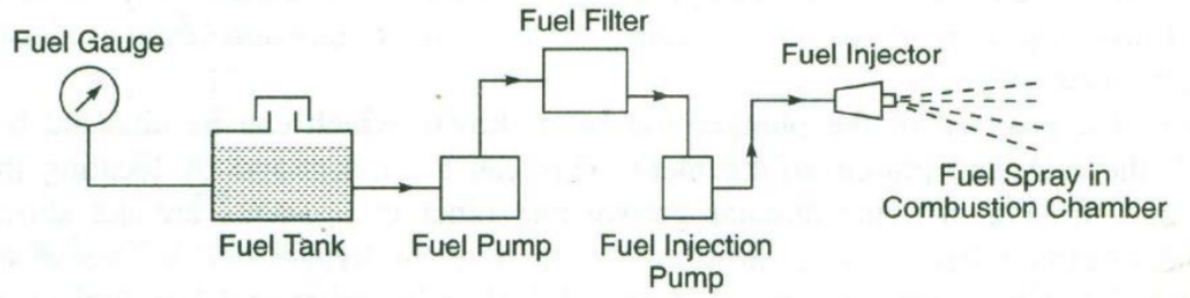


Fig. 8.1 Layout of Fuel Injection System

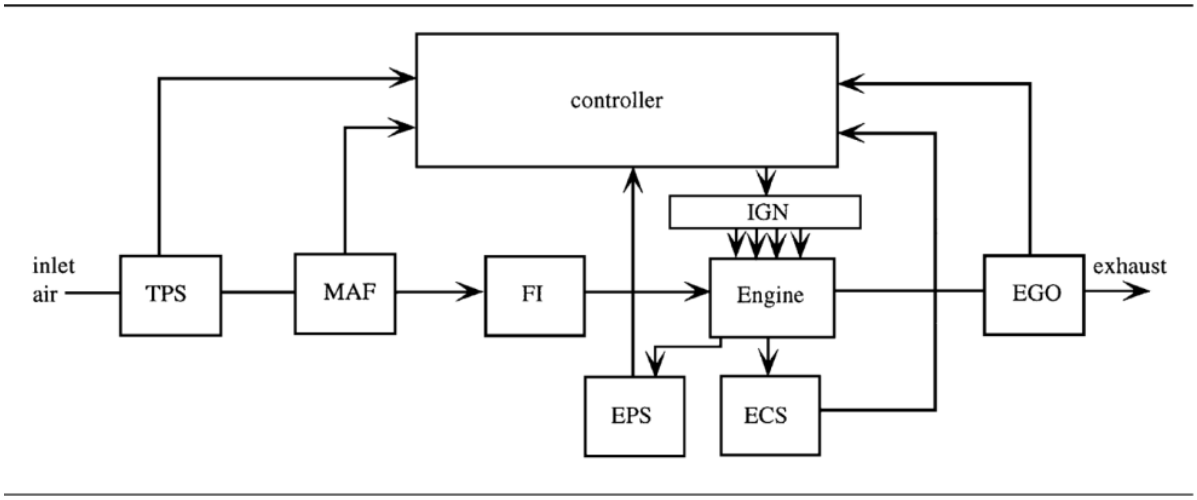
The fuel injection pump has a small plunger and a small stroke. The movement of the plunger cannot create sufficient vacuum to suck fuel from the fuel tank. Therefore an auxiliary fuel pump is used to lift the fuel above the level of the injection pump

• The fuel injector has either a single hole nozzle or a multi-hole nozzle. A jet of fuel passes through this hole at high velocity and atomizes.

Fuel injector

• The purpose of an injector is to atomize or to divide the fuel into fine droplets and to direct the spray suchthat every fuel particle finds sufficient air to burn completely.

Electronic Fuel Control Operation



Air Intake System,

The function of the air intake system is to allow air to reach your engine. Oxygen in the air is one of the necessary elements for the engine combustion process. On most modern vehicles the intake system consists of a plastic air box which housing a paper air filter. Before air enters the system the filter removes small dirt particles and debates. The air intake system draws air through the filter and along pipework to the throttle body. Some systems may contain MAF (Mass Air Flow) sensor which is used by the ECU to determine the mass of air entering a fuel-injected internal combustion engine.

AIR INTAKE MAF

A MAF sensor determines the mass of air flowing into the engine's air intake system. The measured Airflow has a direct effect on the fuelling. Stock and Revo calibrations are specific to (unless otherwise specified) a standard scaled MAF sensor housing. There are two common types of mass airflow sensors in use on automotive engines. They are the vane meter and the hot wire.

There are many aftermarket intakes available, but not all of them have correct MAF housing scaling. When upgrading your intake system correct MAF scaling is important, especially when tuning your vehicle. Correct scale mass airflow sensor housing is an important part of the design and testing process of all Revo intakes.

Air/ Fuel Management

Air flow through the engine is either measured by a sensor inserted in the air intake duct or calculated by the PCM through precise measurement of intake manifold pressure, throttle position and engine speed. All the air entering the engine needs to be accounted for by this system in order for the PCM to calculate the correct amount of fuel to be added to the air/fuel mixture; resulting in complete combustion and proper catalytic converter operation. If unmeasured air enters the engine not enough fuel will be added resulting in incomplete combustion and misfires. Under these

conditions the engine is less fuel efficient and runs the risk of adding excessive pollution back into the air we breathe.

Fuel Tank

The fuel tank stores fuel until it is needed by the injectors for combustion in the engine. It is usually constructed from metal or composite plastic materials. The fuel tank has an inlet pipe and an outlet pipe.

Fuel Pump

Fuel injection systems operate at high fuel pressures, typically in the 40-60 psi range, or higher for direct injection. To achieve proper pressure and volume flow fuel pumps are generally electric motors located in the fuel tank, utilizing the fuel in the tank to cool the pump and to ensure a steady supply of fuel.

Fuel Rail

Fuel rails are used on engines with multi-point fuel injection systems. A fuel rail is basically a pipe or two connected pipes (sometimes called a fuel manifold) used to deliver fuel to the individual fuel injectors on the engine.

Fuel Injectors

A fuel injector is an electronically controlled solenoid valve that opens and closes many times per second. When the injector is energized, an electromagnet moves a plunger that opens the valve allowing the pressurized fuel to squirt out through a tiny nozzle. The nozzle is designed to atomize the fuel for better combustion.

Fuel Pressure Regulator

The function of the fuel pressure regulator is to maintain the desired fuel pressure delivered to the fuel injector under all engine operating conditions.

Mass Air Flow Sensor

The mass air flow sensor (MAF) is used to measure the flow rate of air entering a fuel injected engine.

Manifold Absolute Pressure Sensor

On some fuel injection systems a manifold absolute pressure sensor (MAP) is used to calculate air volume entering the engine.

Oxygen Sensor

The sensor tells the engine management computer (PCM) if the fuel mixture is burning rich (less oxygen) or lean (more oxygen).

Throttle Position Sensor

The throttle position sensor (TPS) is usually connected to the throttle plate shaft in the throttle body. The TPS reads the angle of the throttle valve and transmits an electrical signal to the PCM.

Powertrain Control Module (PCM)

The PCM's job is to manage the powertrain. This includes the engine's ignition system, fuel injection system and emission controls. The PCM receives inputs from a wide variety of sensors and switches. In turn the PCM controls -directly or indirectly- relays, solenoid and other components to achieve proper ignition timing, fuel delivery and proper treatment of pollutants.