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Department of Mechanical Engineering
RV College of Engineering®, Bengaluru – 560059

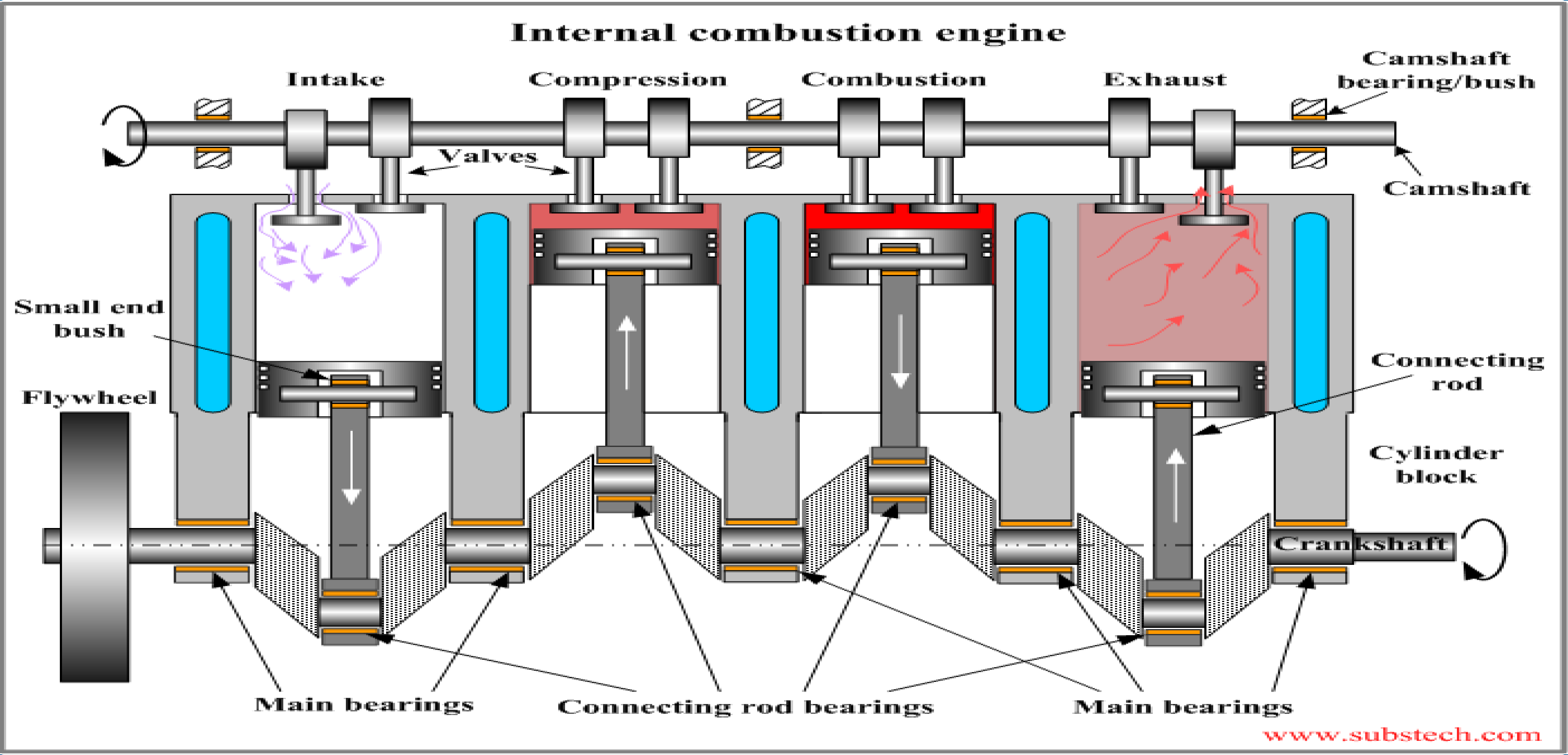
ELEMENTS OF MECHANICAL ENGINEERING

IC ENGINES

UNIT-III (7 hours)

Internal Combustion Engines: Classification of IC Engines, parts of IC engine and their function. Working of 2 stroke and 4 stroke petrol and diesel engines. Brake power, indicated power, mechanical efficiency, thermal efficiencies, and specific fuel consumption, simple numerical.

IC ENGINES


Internal combustion engine
Intake
Compression
Combustion
Exhaust
Camshaft bearing/bush
Valves
Camshaft
Small end bush
Flywheel
Connecting rod
Cylinder block
Crankshaft
Main bearings
Connecting rod bearings
Main bearings
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Any type of engine which derives heat energy from the combustion of fuel and converts it in to mechanical work is termed as a ***heat engine.***

Heat engines may be classified in to two main types;

1)External Combustion engines (EC engines)

2)Internal combustion engines (IC engines)

In an *external combustion engine*, the combustion of fuel takes place outside the engine cylinder.

Ex: Steam engines

In an *internal combustion engine*, the combustion of fuel takes place inside the engine cylinder.

Ex: Petrol engines, Diesel engines.

ADVANTAGES OF I.C ENGINES OVER E.C ENGINES

- High efficiency:
- Simplicity
- Compactness
- Light weight
- Easy starting
- Comparatively low cost

CLASSIFICATION OF IC ENGINES:

I.C. Engines are classified according to:

1. Nature of thermodynamic cycle

- Otto cycle engine.
- Diesel engine.
- Dual combustion cycle engine.

2. Type of the Fuel used

- Petrol engine.
- Diesel engine.
- Gas engine.
- Bi-fuel engine.

3. Number of strokes

- Two stroke engine.
- Four stroke engine.

4. Type of Ignition

- Spark ignition engine, known as S.I. Engine.
- Compression ignition engine, known as C.I engine.

5. Number of Cylinder as

- Single cylinder engine.
- Multi cylinder engine.

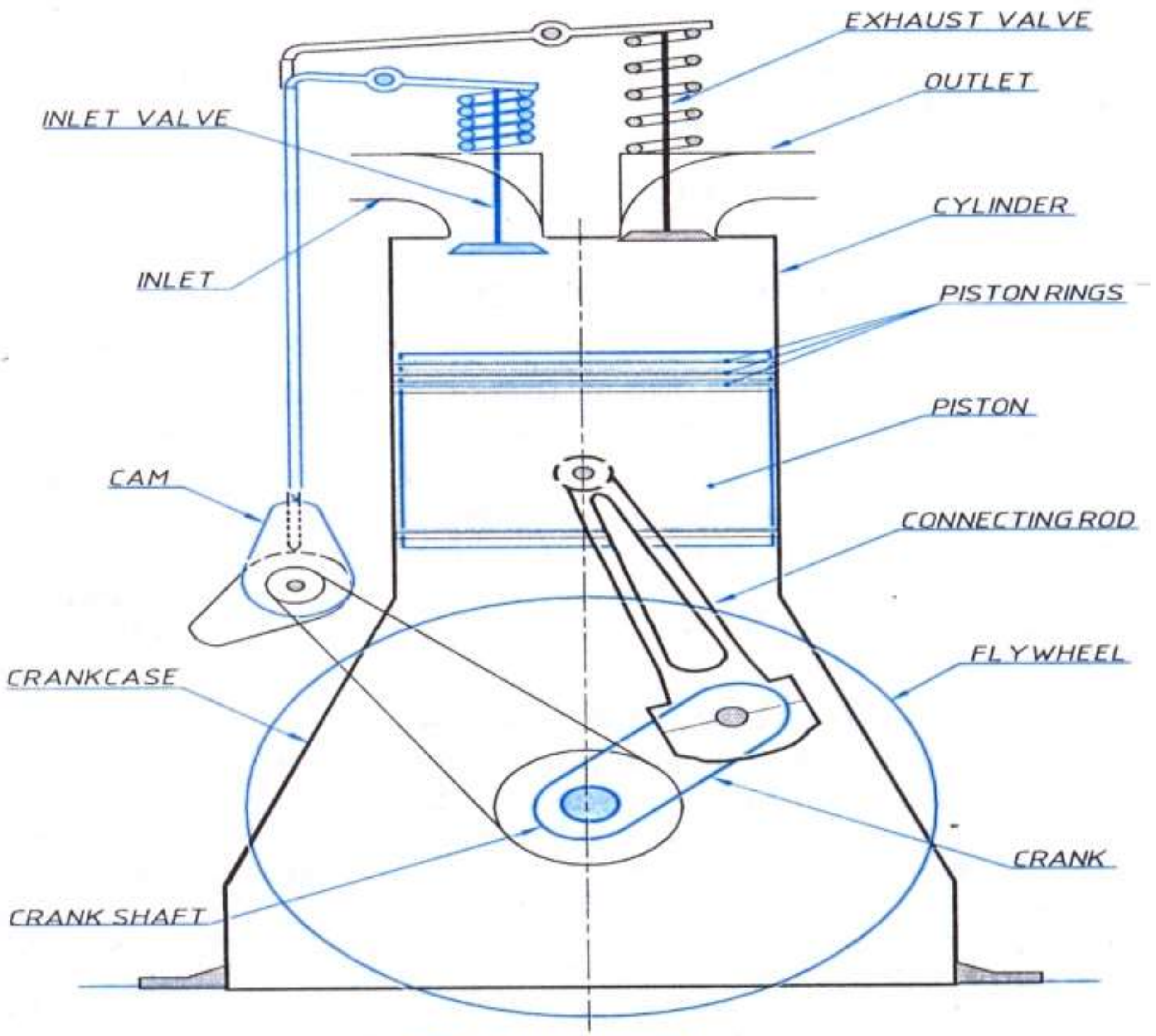
6. Position of the Cylinder

- Horizontal engine.
- Vertical engine.
- Radial engines
- In-line engines

7. Method of Cooling

- Air cooled engine.
- Water cooled engine.

PARTS OF I C ENGINE



Parts of I.C.Engine

PARTS OF I C ENGINE

- Cylinder
- Piston
- Piston rings
- Connecting rod
- Crank and crankshaft
- Valves
- Flywheel
- crankcase

1.Cylinder:

- It is made of grey cast iron.
- Fuel is burnt inside the cylinder and power is developed by action of hot gases on the piston.

2.Cylinder head:

- One end of the cylinder is closed by means of are movable cylinder head which is made of cast iron with alloying elements such as nickel, chromium, molybdenum, etc.

- Cylinder head houses the inlet & exhaust valves.

3.Piston:

It is a close fitting hollow cylindrical plunger moving to & fro inside the cylinder.

It is made of aluminium alloys for light weight.

The power developed by the combustion of fuel is transmitted by the piston to the crankshaft through the connecting rod.

4. Piston rings:

These are metallic rings made of cast iron. They are inserted in to the circumferential grooves provided at the top end of the piston. Piston rings maintain a gas tight seal between the cylinder & the piston. They also help in conducting the heat from piston to cylinder.

5.Connecting rod:

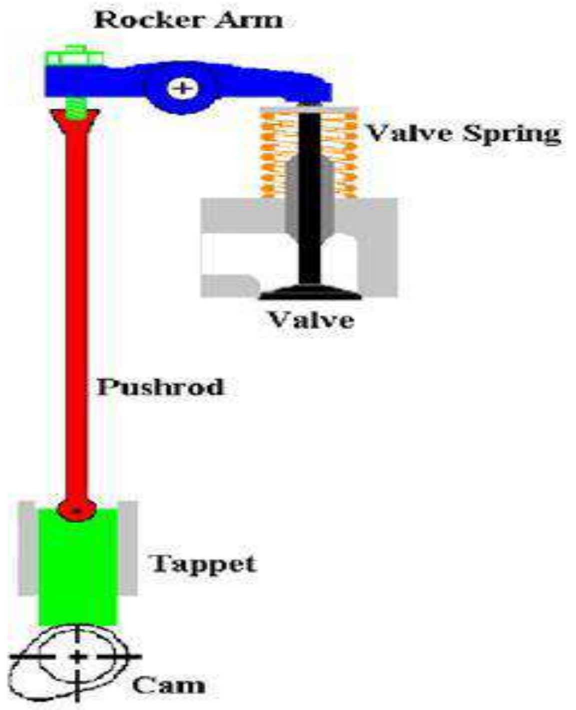
- It is the link that connects the piston and the crankshaft by means of pinjoints.
- It converts the linear motion of the piston in to rotary motion of the crankshaft.
- Connecting rods are made of alloy steels.

6.Crank & Crankshaft:

- Crank is a lever (made of carbon steel) that is connected to the end of the connecting rod by a pin joint.
- The other end of the crank is rigidly connected to a shaft known as ‘*crankshaft’.*
- As the connecting rod oscillates, the crank and hence the crankshaft rotate about an axis.

7.Valves:

- Valves are devices which control the flow of in take an exhaust gases to & from the cylinder.
- They are also called as '*Poppet Valves*' and are operated by means of cams driven by the crankshaft through belt or gears



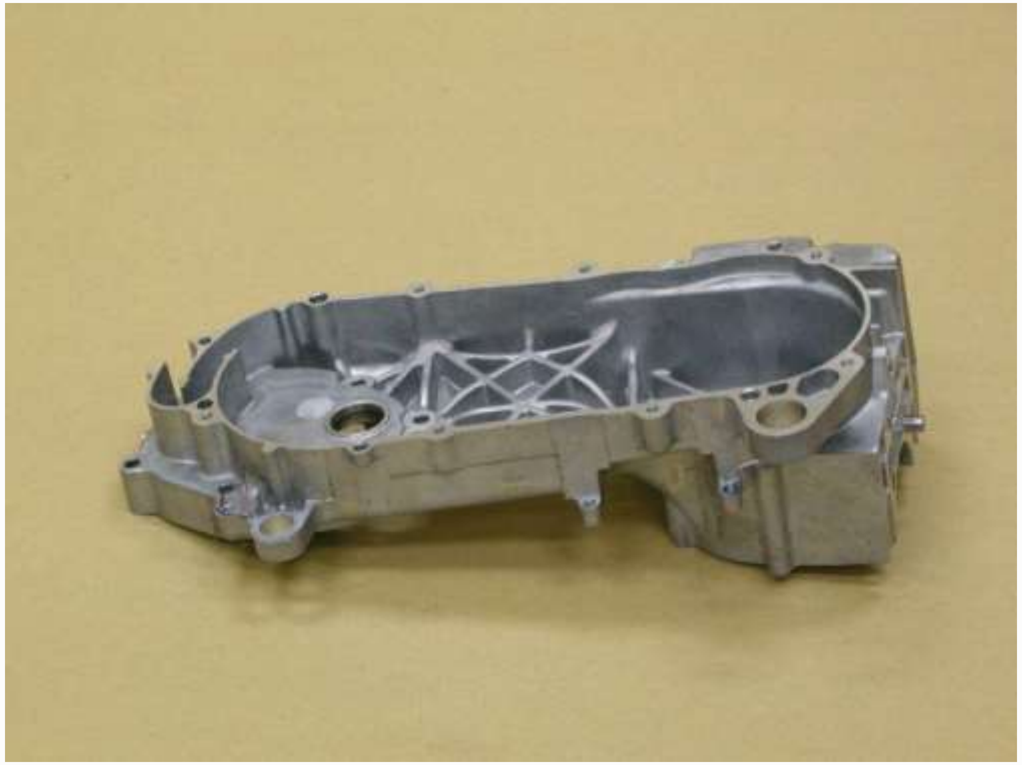
8.Flywheel:

- It is a heavy wheel mounted on the crankshaft of the engine to maintain uniform rotation of the crankshaft.
- It absorbs kinetic energy during power stroke & delivers energy during other strokes.
- Fly wheel is made of cast iron.

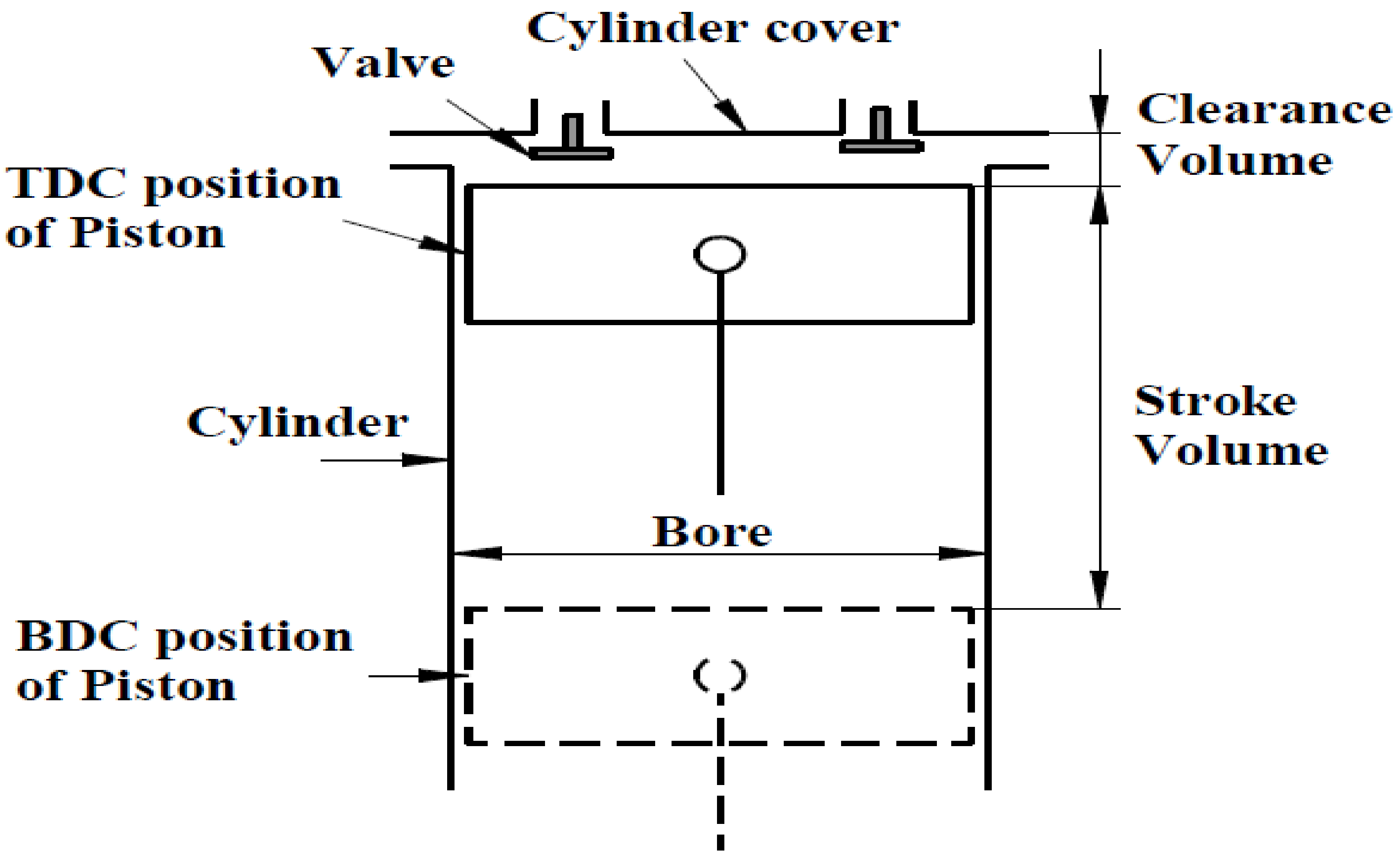
9. Crankcase:

It is the lower part of the engine serving as an enclosure for the crankshaft.

It also serves as a sump (reservoir) for lubricating oil.

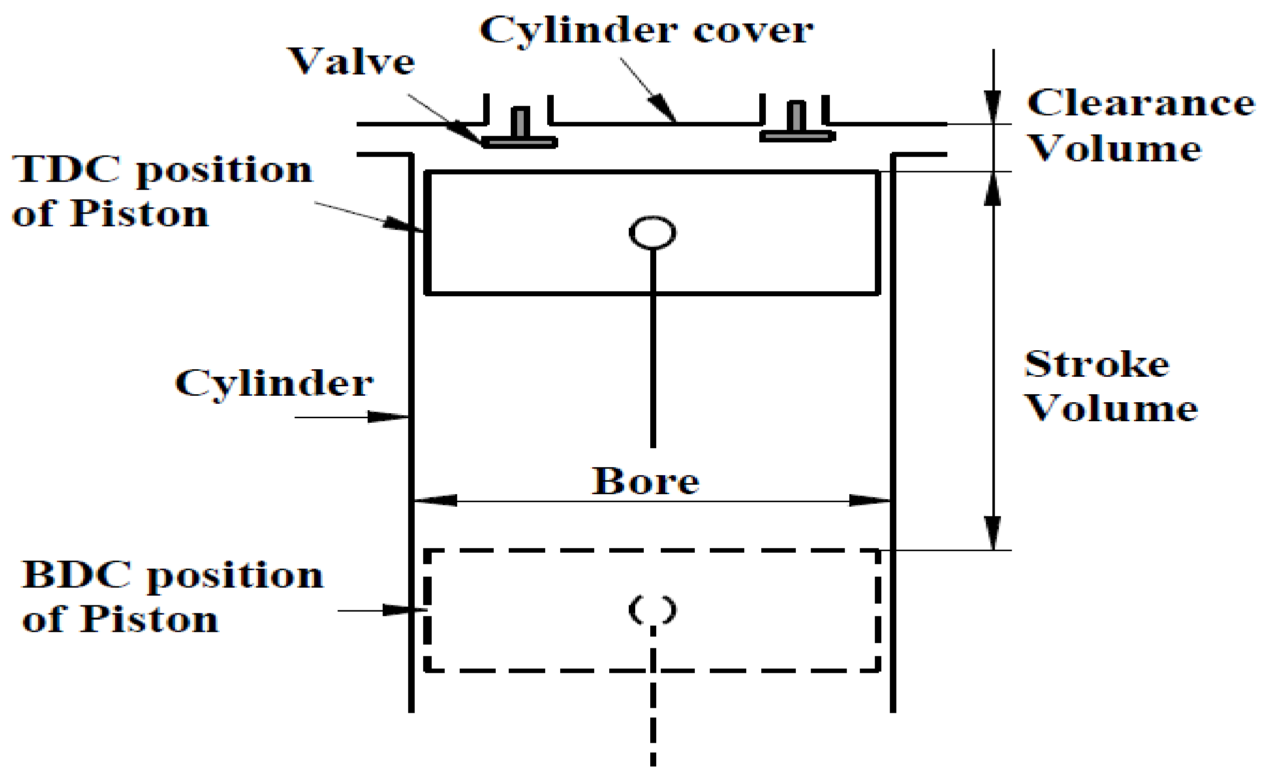


I.C ENGINE TERMINOLOGY



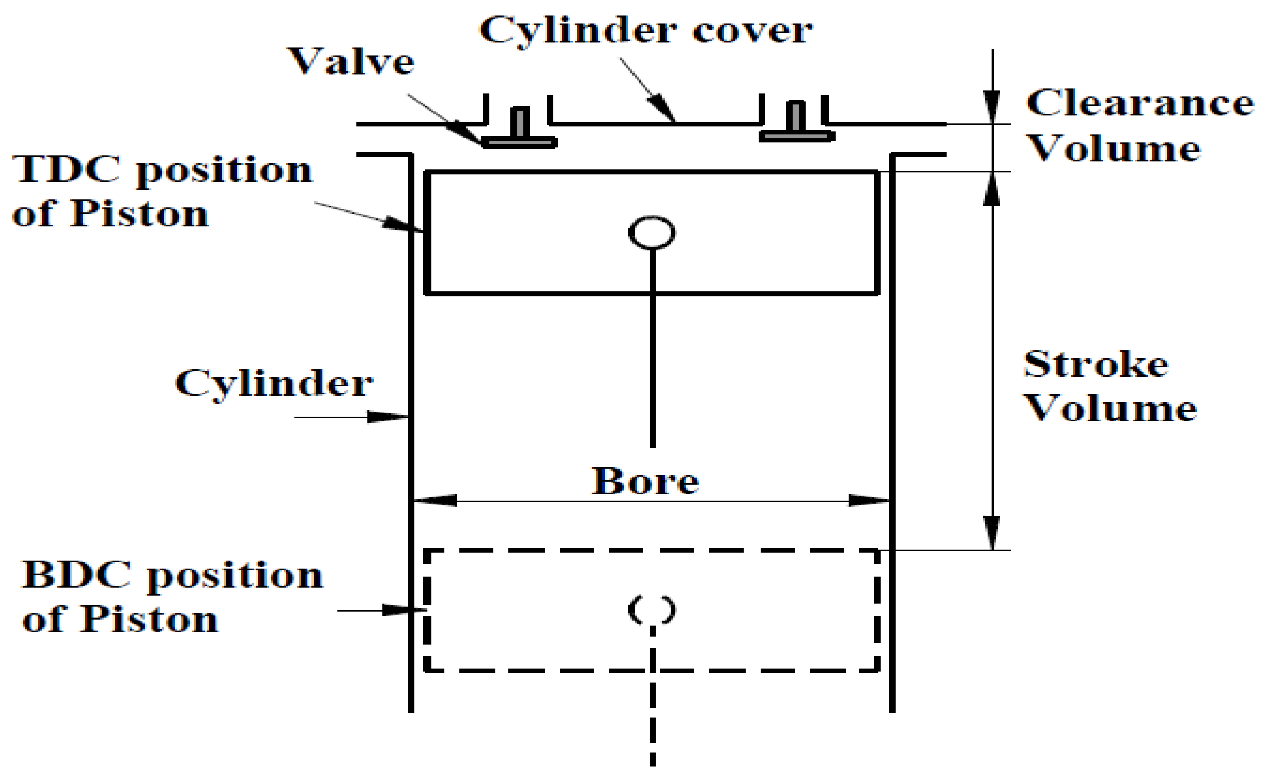
I.C ENGINE TERMINOLOGY

- **Bore**- inside diameter of the cylinder
- **crank radius- Rc** it is the linear distance between the shaft centre and crank pin centre. It is equal to half the stroke length



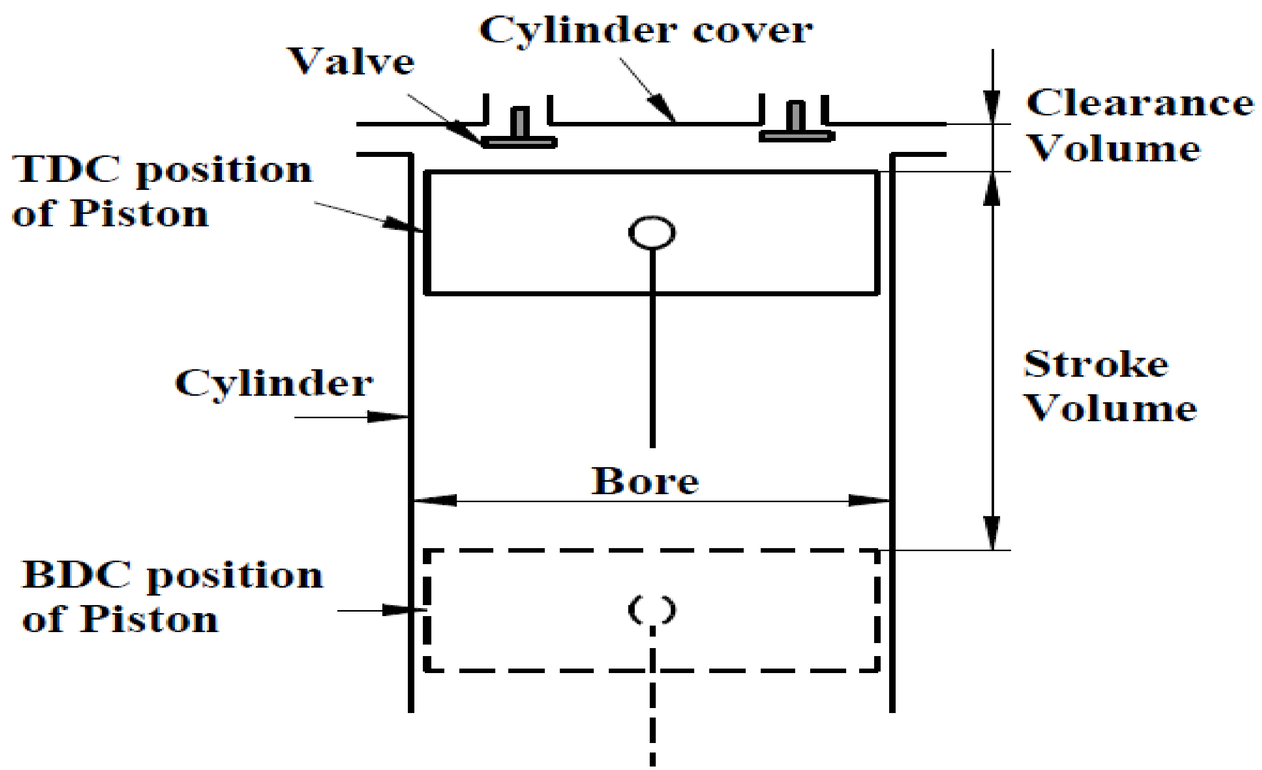
I.C ENGINE TERMINOLOGY

Top Dead centre / inner dead centre - it is the extreme position of the piston towards cover end side of the cylinder. The crank pin comes between the piston and the crankshaft.



I.C ENGINE TERMINOLOGY

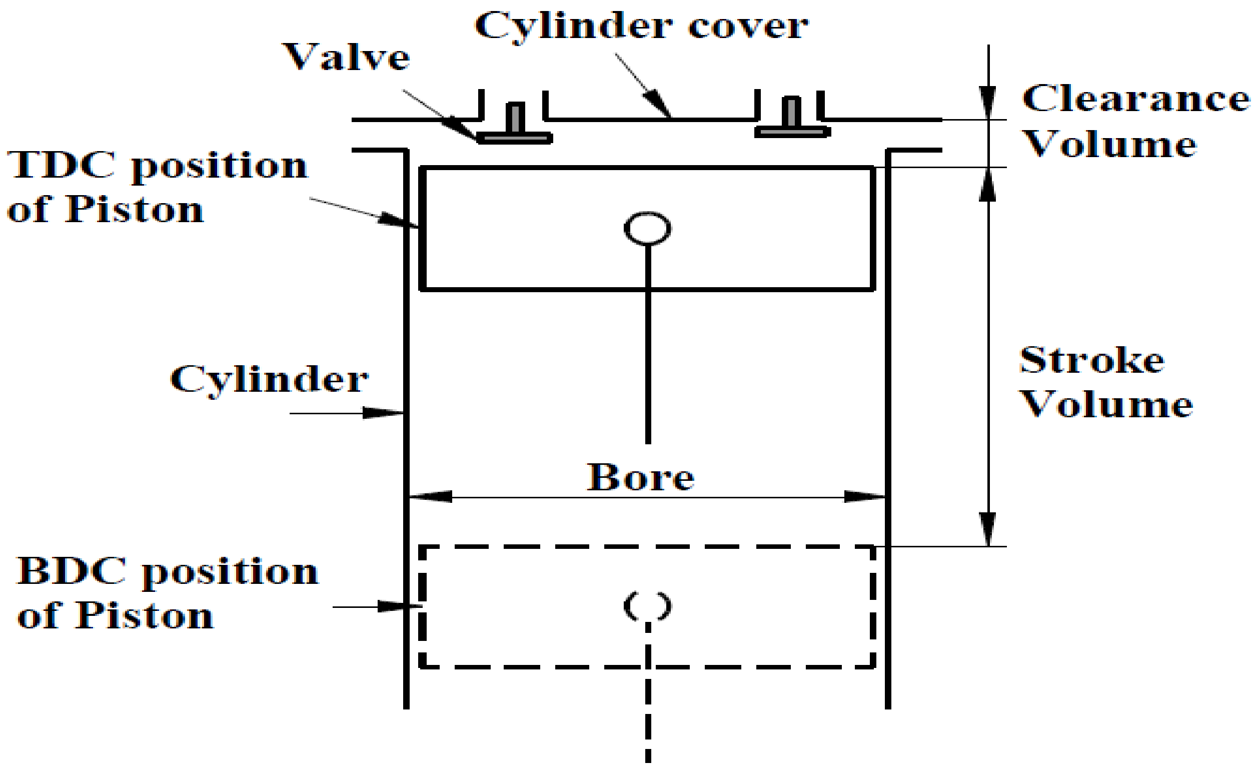
Bottom dead centre / outer Dead centre: It is the extreme position of the piston towards the crank end side of the cylinder. The crank pin moves to the farthest distance from the cylinder.



I.C ENGINE TERMINOLOGY

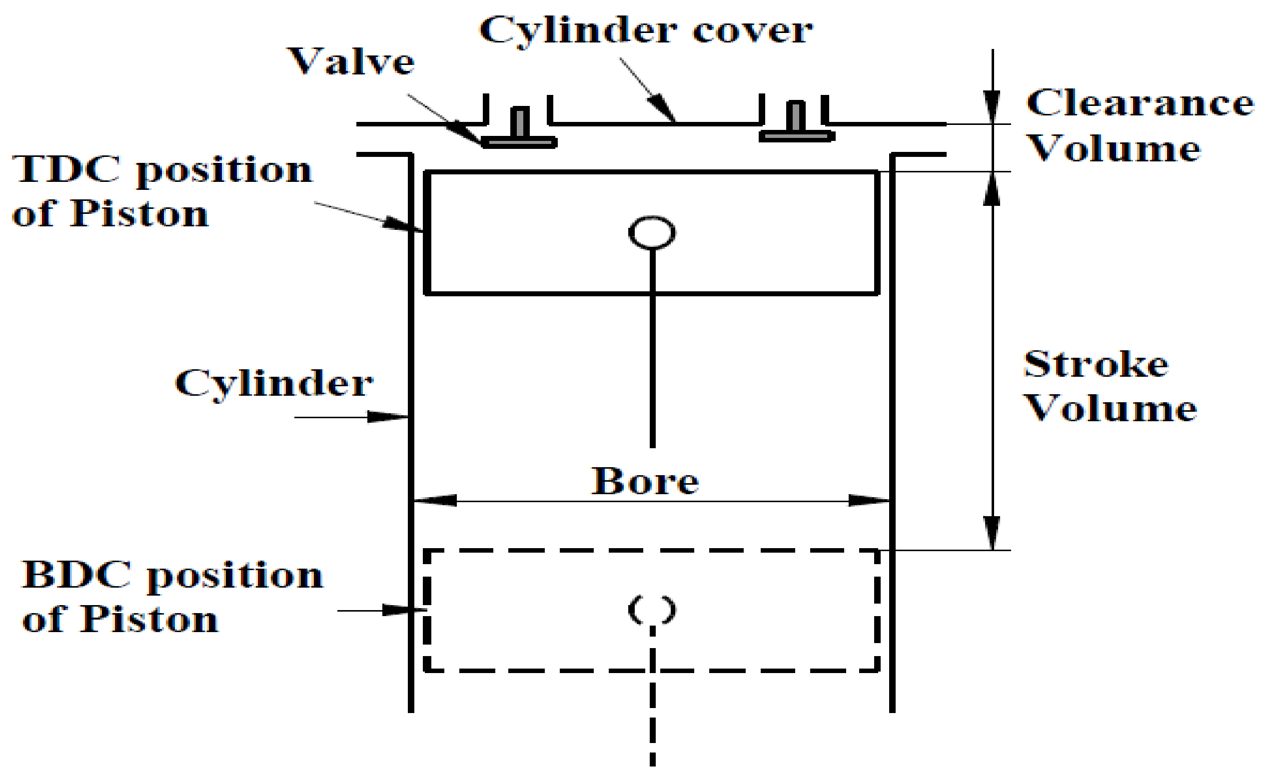
Swept volume : It is the volume through which the piston sweeps during a stroke.

It is equal to the product of surface area of piston and its stroke length.



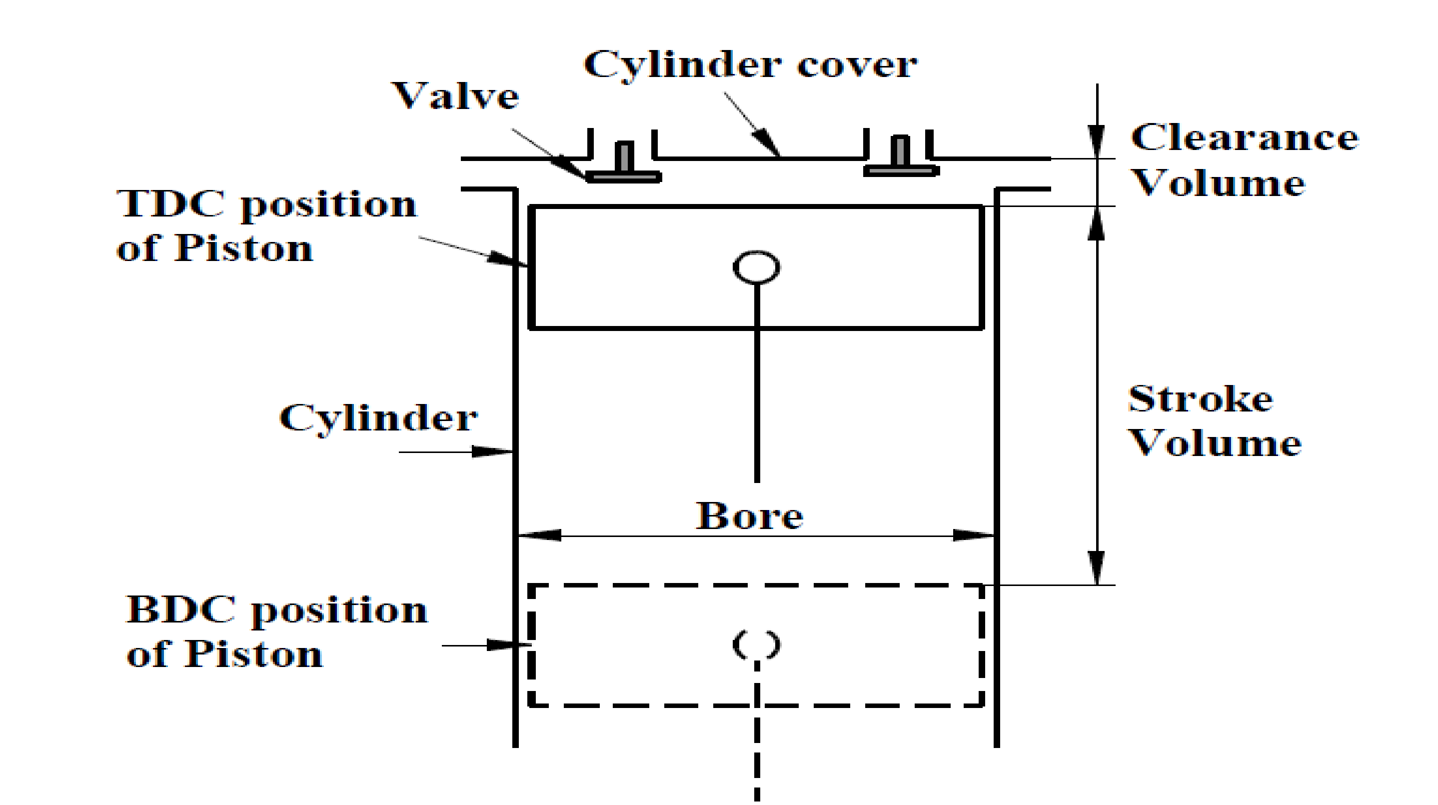
I.C ENGINE TERMINOLOGY

Stroke- ($L=2r_c$) It is the linear distance travelled by the piston from one dead centre position to the another dead centre position. It is equal to twice the crank radius.



I.C ENGINE TERMINOLOGY

Clearance volume V_c- It is the volume included between the top of the piston and the cylinder head when the piston is at TDC . It is expressed as a percentage of the swept volume . The piston never touches the cylinde

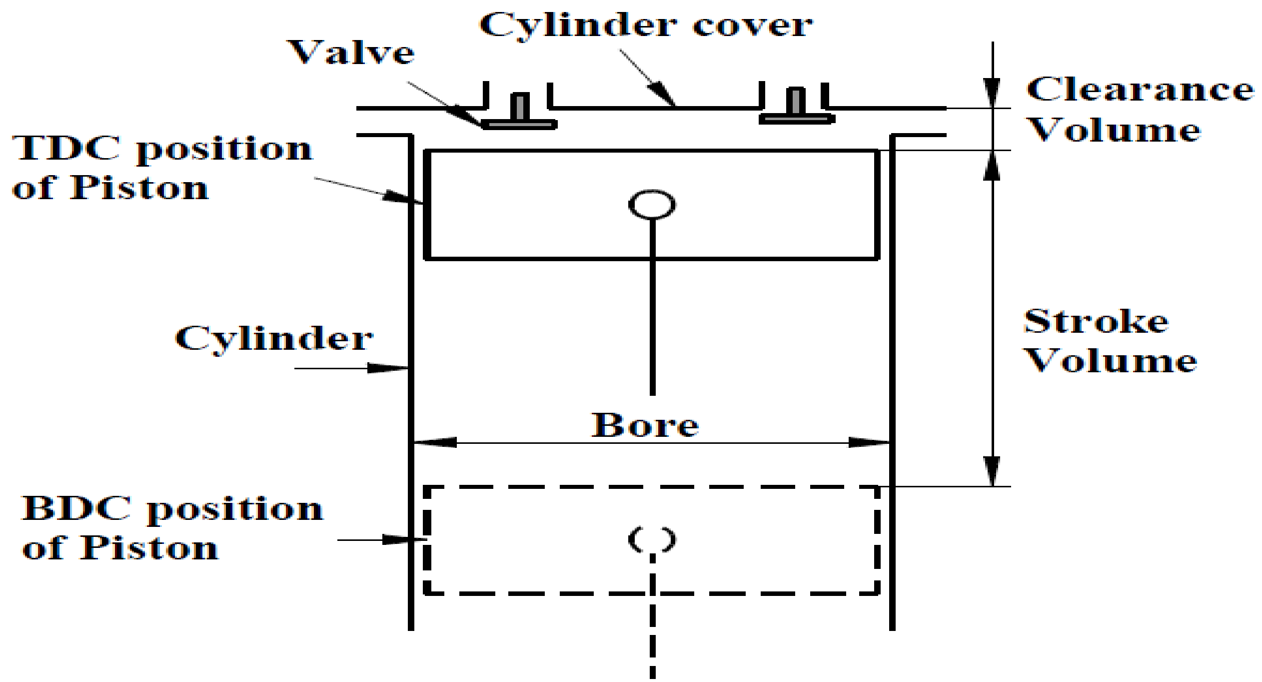


I.C ENGINE TERMINOLOGY

Compression Ratio: It is the ratio of the total cylinder volume to the clearance volume

For petrol engine CR varies from 4:1 to 10:1

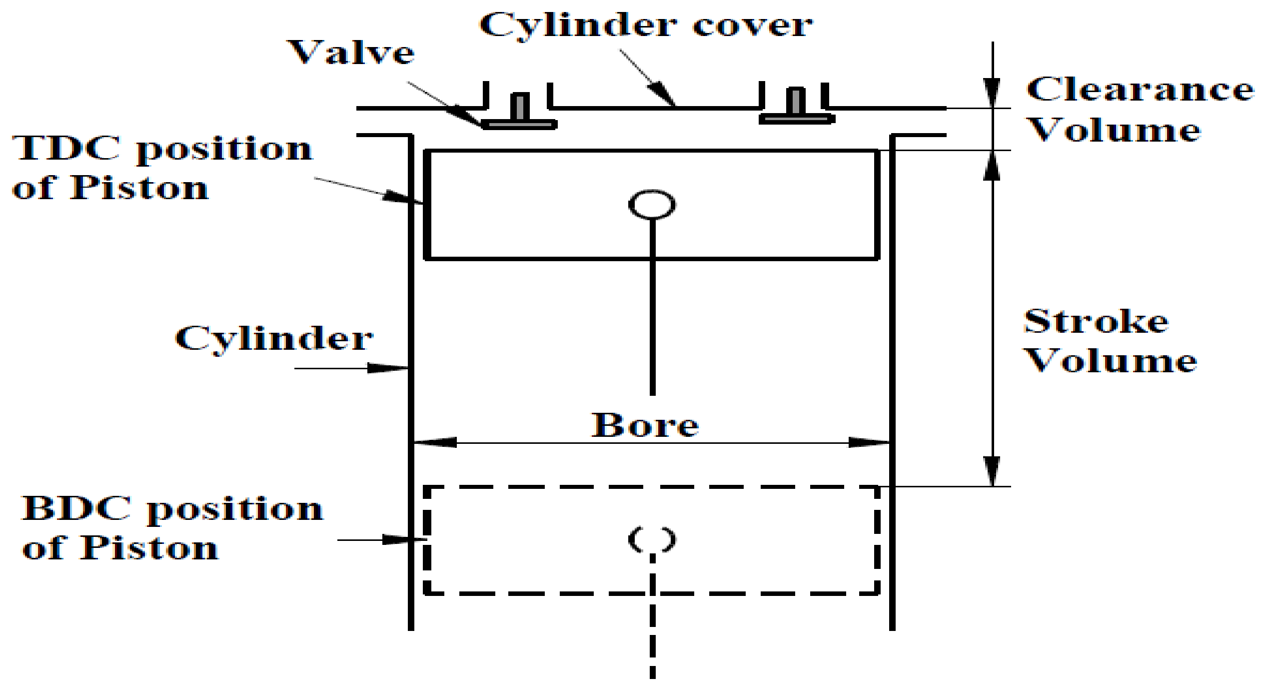
For diesel engine CR varies from 12:1 to 22:1



I.C ENGINE TERMINOLOGY

Piston Speed: It is the distance travelled by the piston per unit time.

Cycle of Operation: It is complete series of events



FOUR STROKE CYCLE PETROL ENGINE

Petrol engines work on the principle of theoretical ***Otto cycle.***

- It is also known as *constant volume cycle*, shown in fig.
- The piston performs four strokes (one each in half revolution of crankshaft) to complete the working cycle. (in 2 revolutions of crank shaft)
- The four strokes are:

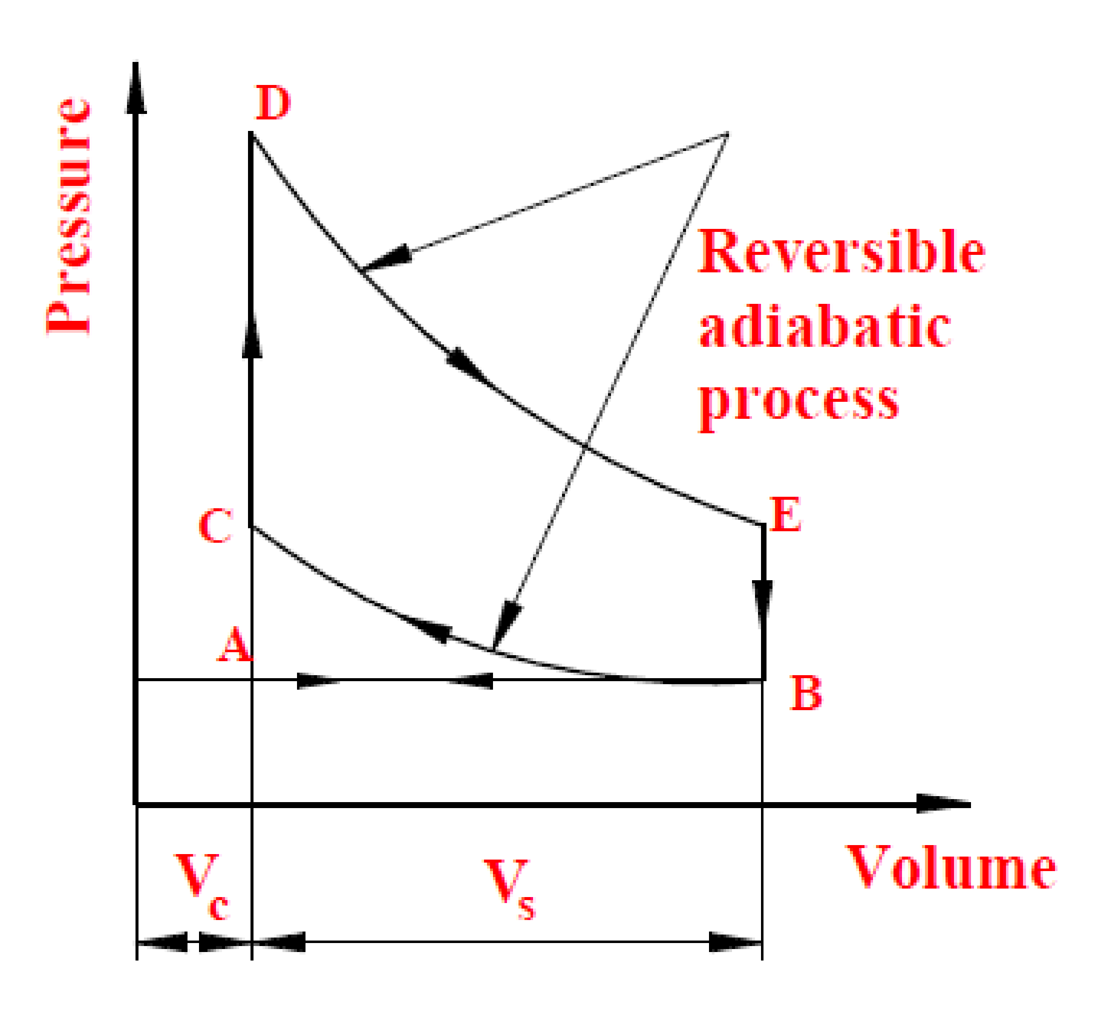
(i) Suction

(ii) Compression

(iii) Working (or) Power stroke

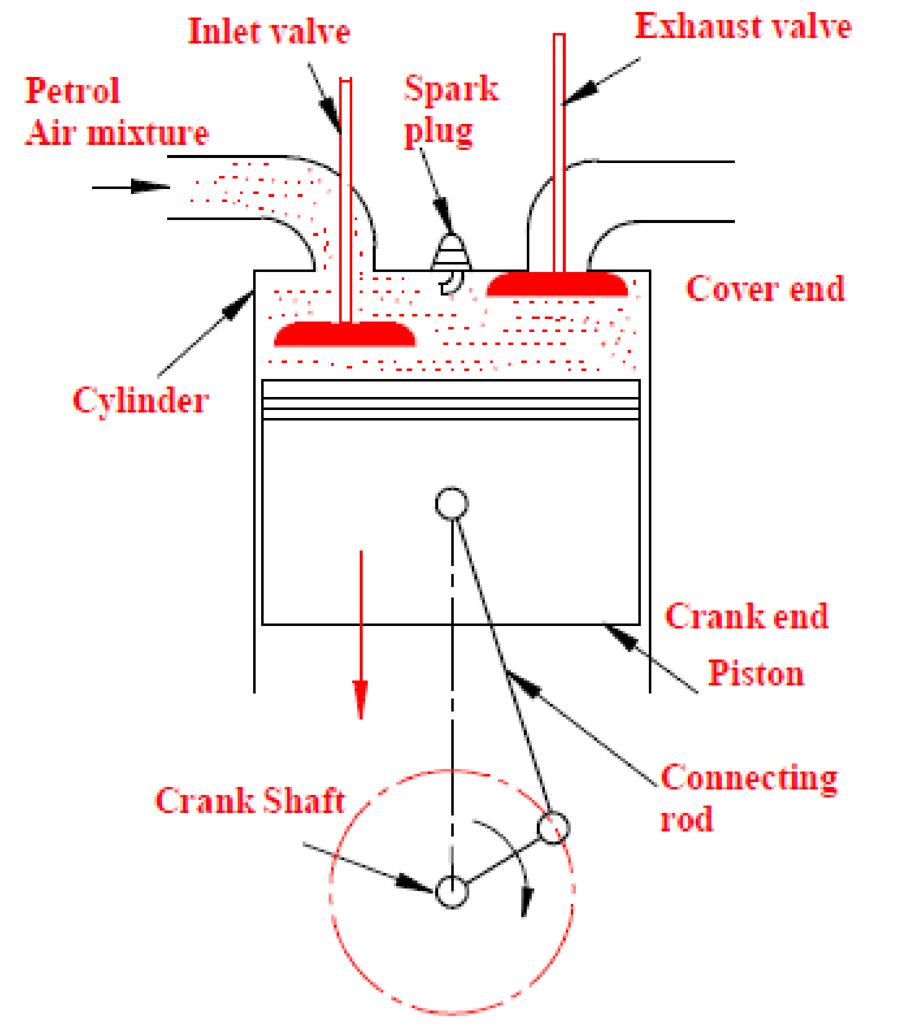
(iv) Exhaust stroke

FOUR STROKE CYCLE PETROL ENGINE



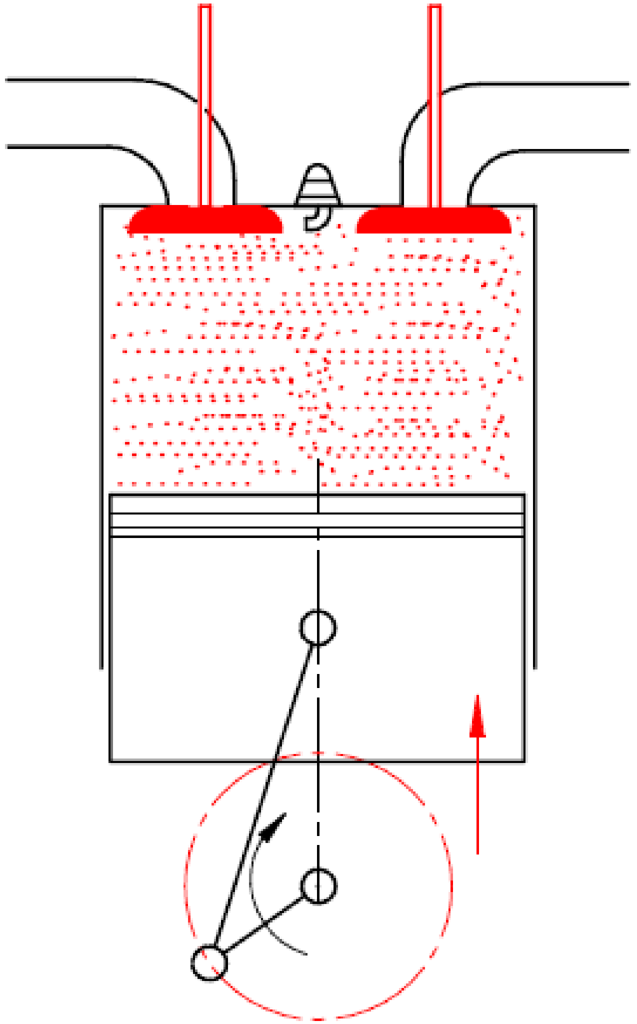
P-V Diagram

SUCTION STROKE



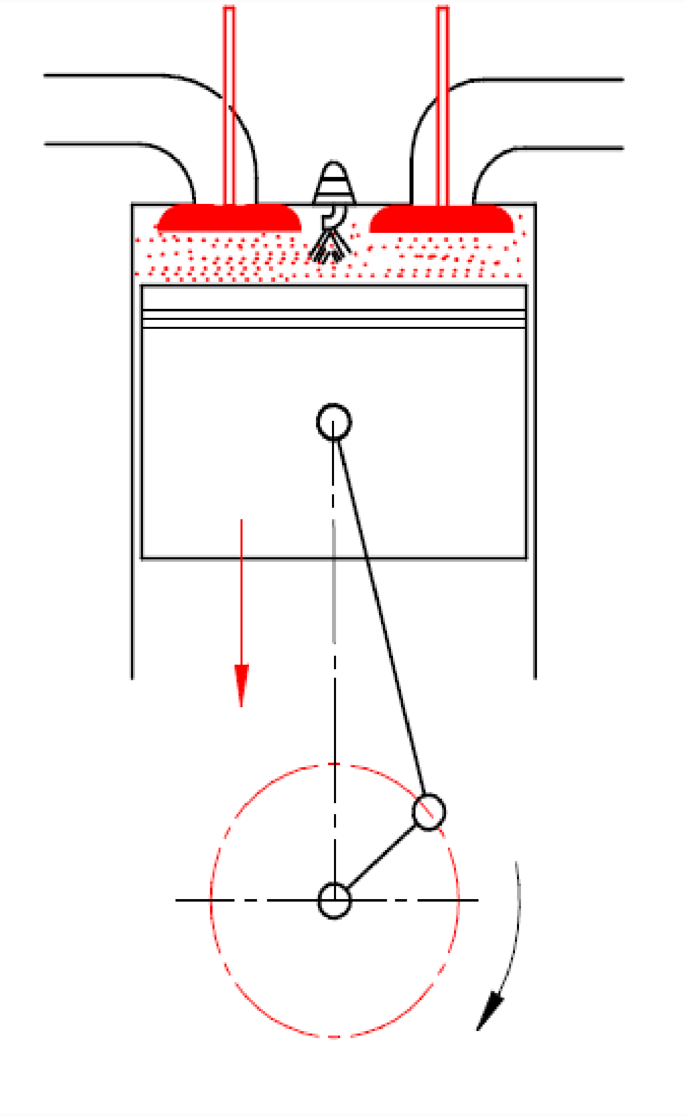
- During suction stroke, the inlet valve is open and exhaust valve is closed.
- The piston moves from cover end to crank end during half revolution of crankshaft.
- The air-petrol mixture is drawn into the cylinder and completely fills the cylinder.
- Suction takes place at atmospheric pressure and is indicated by horizontal line AB in the p-v diagram.
- The process is initiated by ‘***cranking’*** using external energy source

COMPRESSION STROKE



- During this stroke, both inlet & exhaust valves are closed. The piston moves from crank end to cover end during half revolution of crankshaft.
- The air fuel mixture in the cylinder will be compressed adiabatically as shown by curve BC in the p-v diagram.
- At the end of compression stroke, the air-petrol mixture is ignited by an electric spark given out by the ***spark plug***.
- The combustion of the mixture causes increase in pressure as shown by line CD in P-V diagram.

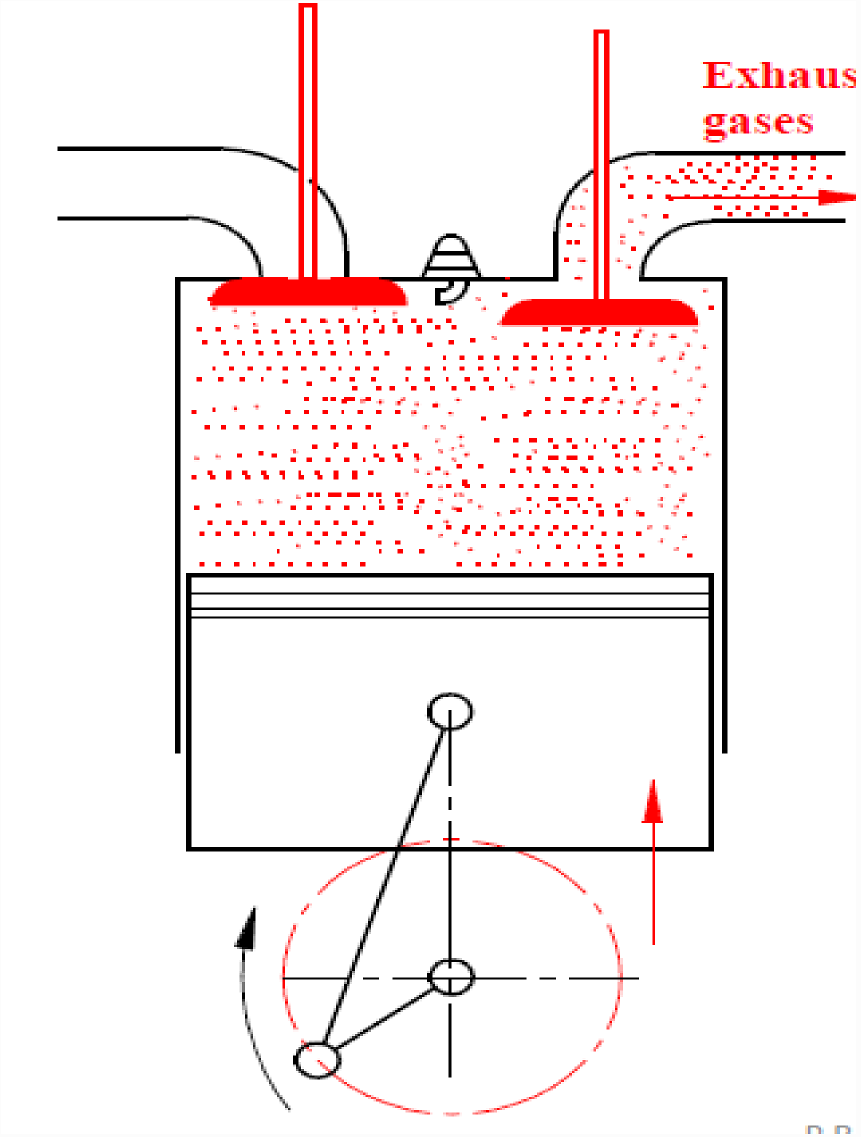
POWER STROKE



During this stroke, both inlet & exhaust valves are closed.

- The expansion of gases due to heat of combustion exerts a pressure on the piston forcing it to move towards the crank end.
- The expansion of gases is indicated by adiabatic process DE in the P-V diagram.
- At the end of this stroke, the exhaust valve will open release the burnt gases to the atmosphere thus bringing down the pressure as indicated by vertical line EB in the P-V diagram

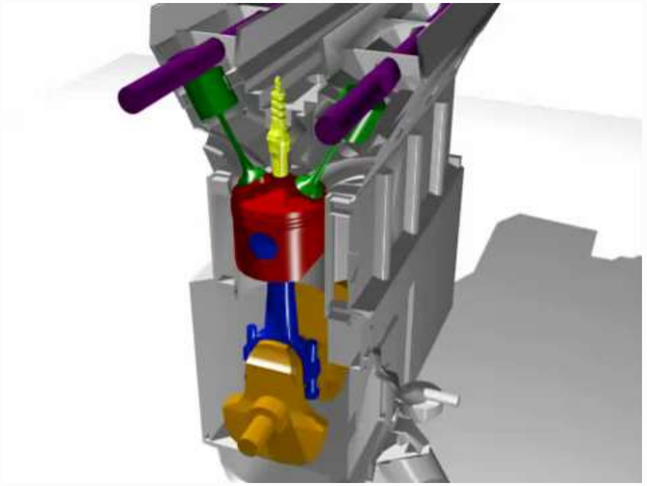
EXHAUST STROKE



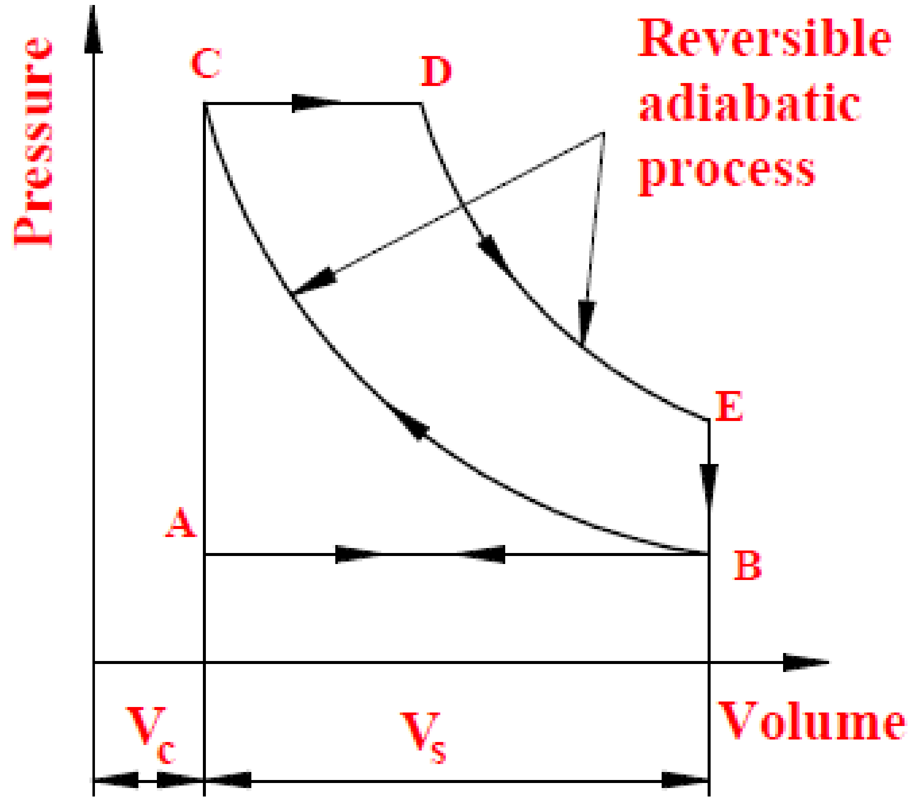
During this stroke, the inlet valve remains closed & the exhaust valve remains open.

- The piston moves from crank end to cover end forcing exhaust gases out of the cylinder.
- The process is indicated by the horizontal line BA in the P-V diagram, thus completing the cycle.
- Thus the cycle is completed in four strokes of the piston or two revolutions of the crankshaft.
- Thereafter, the entire process repeats itself.

FOUR STROKE CYCLE DIESEL ENGINE

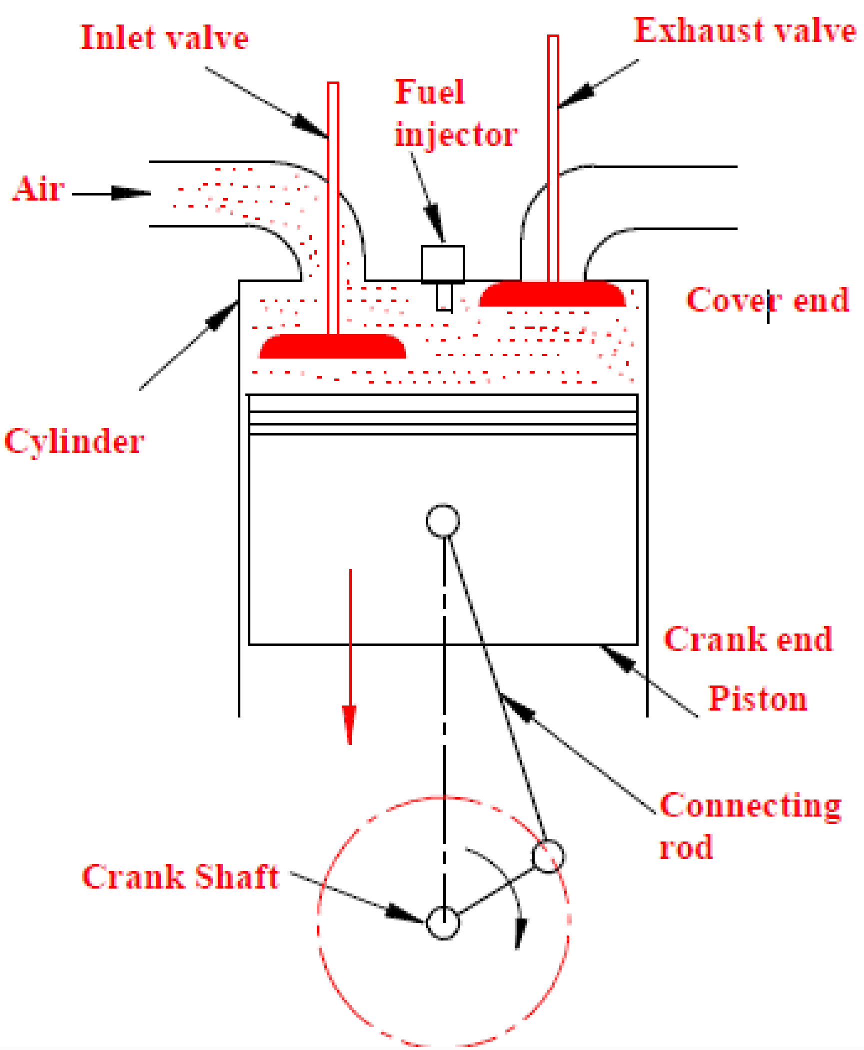


FOUR STROKE CYCLE DIESEL ENGINE



P-V Diagram

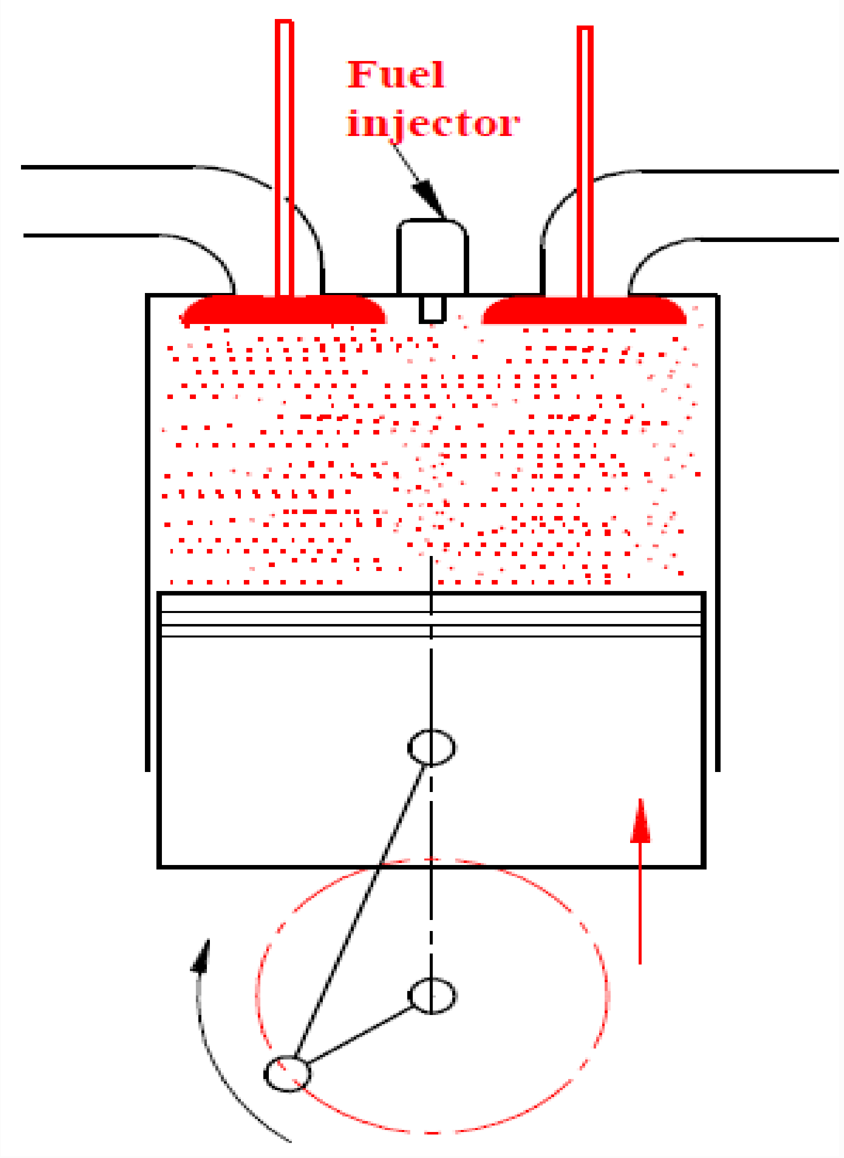
SUCTION STROKE



During suction stroke, the inlet valve is open and exhaust valve is closed.

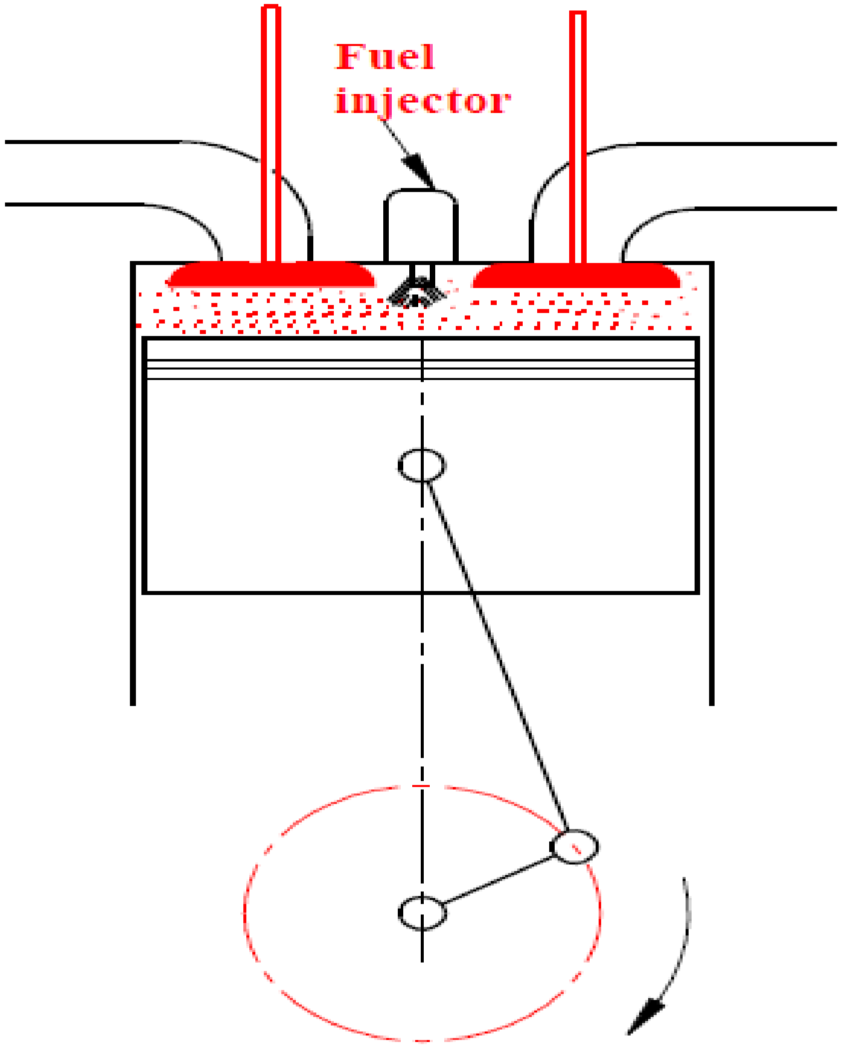
- The piston moves from cover end to crank end during half revolution of crankshaft, and draws ***only air*** into the cylinder.
- The energy required for this stroke is obtained by ‘cranking’ only at the time of starting & by the flywheel while running.
- Suction takes place at atmospheric pressure and is indicated by horizontal line AB in the p-v diagram.

COMPRESSION STROKE



- During this stroke, both inlet & exhaust valves are closed. The piston moves from crank end to cover end during half revolution of crankshaft.
- The air in the cylinder will be compressed adiabatically as shown by curve BC in the p-v diagram.
- At the end of compression stroke, diesel is injected into the hot compressed air as a fine spray by the fuel injector.
- The fuel will be burnt at constant pressure as shown by line CD.

POWER STROKE



During this stroke, both inlet & exhaust valves are closed.

- The expansion of gases due to heat of combustion exerts a pressure on the piston forcing it to move towards the crank end.
- The expansion of gases is indicated by adiabatic process DE in the P-V diagram.
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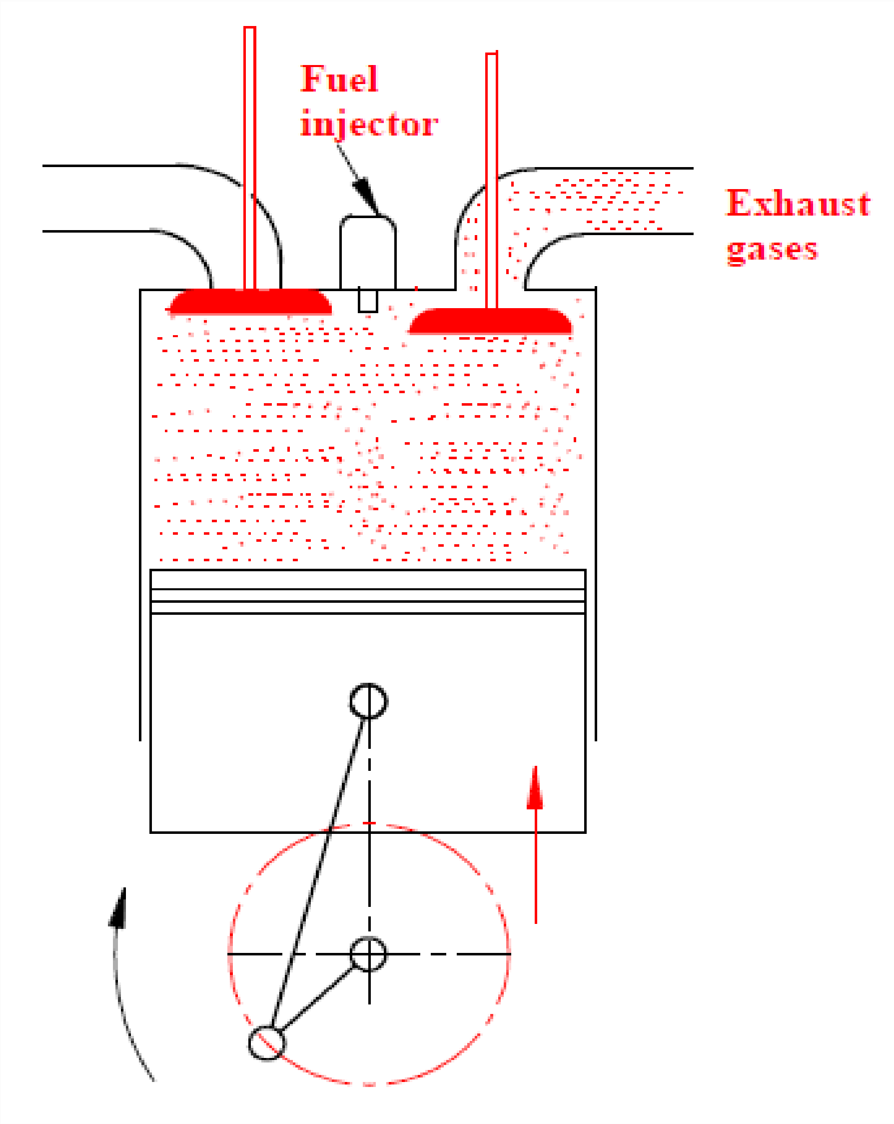
EXHAUST STROKE



During this stroke, the inlet valve remains closed & the exhaust valve remains open.

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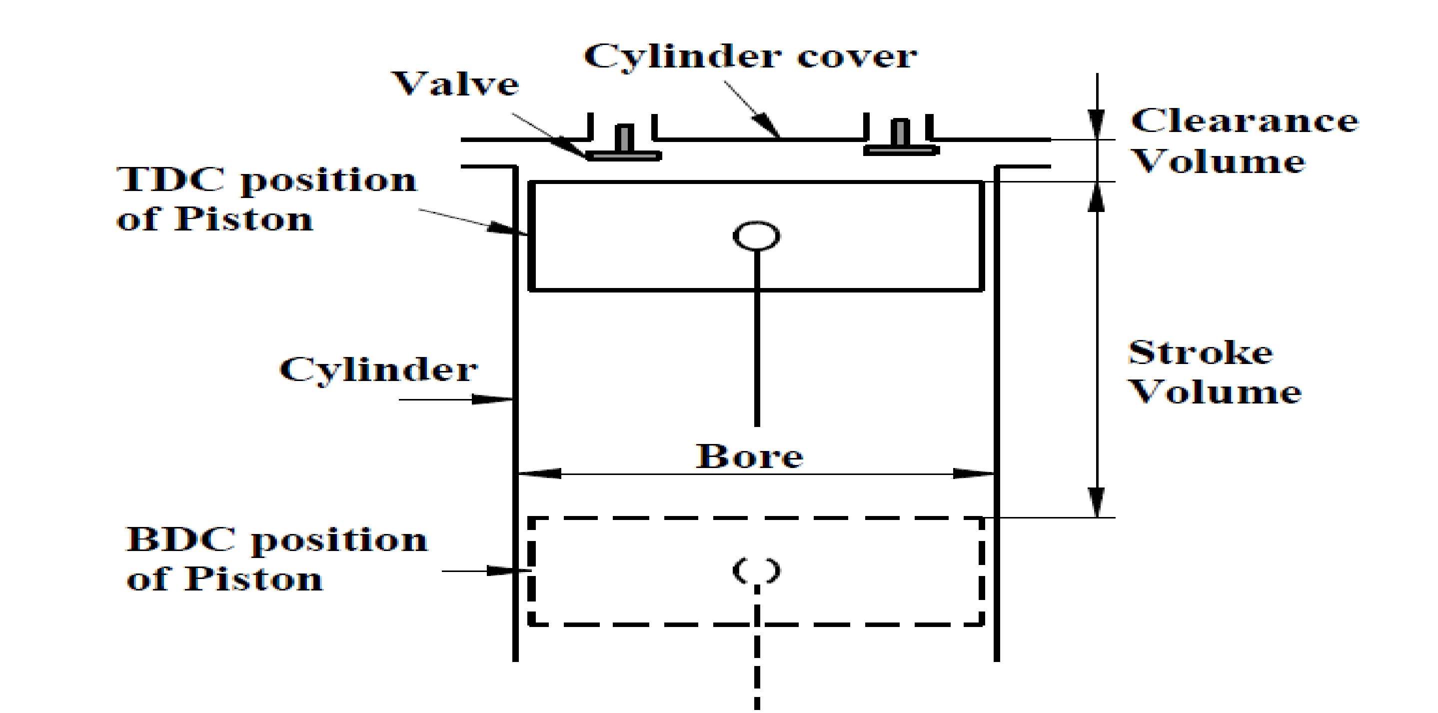
Cycle of Operation: It is complete series of events



IC ENGINES

Petrol Engine	Diesel Engine
Less initial cost & more running cost.	More initial cost & less running cost.
Light weight & occupies less space.	Heavy & occupies more space.
Easy to start even in cold weather.	Difficult to start even in weather
Quantitative governing is used	Qualitative governing is used.
High engine speeds about 3000 rpm	Low engine speeds about 1500 rpm.
Used in light vehicles like cars, motor cycles, Scoters, etc.	Used in heavy duty vehicles like trucks, buses, locomotives, etc.

Four Stroke cycle Engine	Two Stroke cycle Engine
Requires lesser cooling & lubrication.	Requires greater cooling & lubrication.
Less noise while running as the exhaust valves open gradually.	More noise due to sudden opening of exhaust port & release of gases.
Engine crankshaft can rotate only in one direction.	Engine crankshaft can rotate in either direction.
Mechanical efficiency is less because of more moving parts.	Mechanical efficiency is less because of less moving parts such as valves, cams.
Used in cars, buses, trucks, etc.	Used in motorcycles, scooters, etc.

IC ENGINE CALCULATION

INDICATED POWER (IP) :

It is the power produced inside the cylinder and calculated by finding the actual mean effective pressure.

$$IP = 100 P_m LAn / 60 \text{ KW}$$

Where: P_m Mean effective Pressure in bar

L= Stroke Length in meters

A= Cross section area of cylinder bore in m : A=$\pi d^2/4$

Where : d= bore diameter in meters

n=Number of cycles per min; n=N (For 2 stroke engine)

BRAKE POWER (BP):

It is the net power available calculated at the crank shaft is called *Brake Power.*

BP=2πNT/60 KW

Where: N= Rpm of crank shaft

T= Engine torque (in KN-m) =(W -S) R

Where: W= Load on brake drum

S=Spring balance reading

R=Radius of the brake drum

Also **FP =(IP - BP) KW**

Where: FP= Loss of power due to friction

EFFICIENCIES OF ENGINE :

(i) Mechanical Efficiency

η_{mech}= BP/IP*100

(ii) Thermal Efficiency

a. Indicated thermal efficiency

$\eta_{\text{indicated-thermal}} = IP/m_f*C_v \ *100$

Where: m_f =Mass of fuel burnt in Kg/Sec

C_v= Calorific value of the fuel in KJ/Kg

EFFICIENCIES OF ENGINE :

b. Brake thermal efficiency

$$\eta_{\text{Brake-thermal}} = BP/m_f*C_v \quad *100$$

Where: m_f =Mass of fuel burnt in Kg/Sec

C_v= Calorific value of the fuel in KJ/Kg

NOTE:

a. The mean effective pressure is given by

$$P_m = sa / l \quad N/m^2$$

Where: a=Area of the indicator diagram, cm

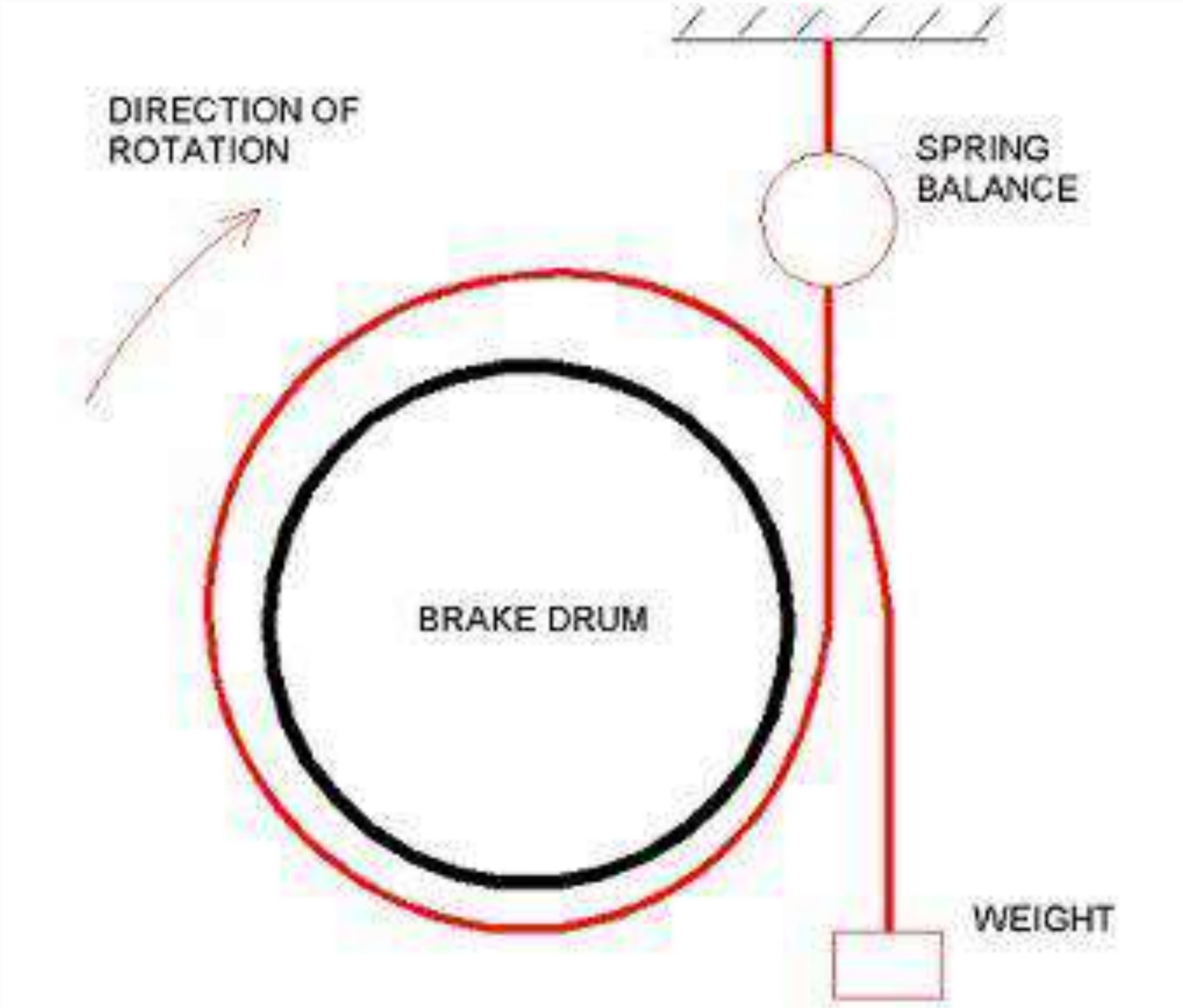
l=Base width of indicator diagram, cm

s= spring constant or spring value, $N/m^2/cm$

b. If a brake load is in Kg, Torque on brake drum

$$T=(9.81*W*R) /1000 \quad KN\text{-}m$$

BRAKE DYNAMOMETER



Electrical Drives:

An electric vehicle (EV) is a vehicle that uses one or more electric motors for propulsion. It can be powered by a collector system, with electricity from extravehicular sources, or it can be powered autonomously by a battery (sometimes charged by solar panels, or by converting fuel to electricity using fuel cells or a generator). EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft and electric space craft.

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EVs first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. Internal combustion engines were the dominant propulsion method for cars and trucks for about 100 years, but electric power remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.

In the 21st century, EVs have seen a resurgence due to technological developments, and an increased focus on renewable energy and the potential reduction of transportation's impact on climate change and other environmental issues. Project Drawdown describes electric vehicles as one of the 100 best contemporary solutions for addressing climate change.

Well-to-wheel analysis

The well-to-wheel analysis is a non standardized method to quantify the impact of transportation of fuels and vehicles regarding energy and climate change.

Usually carbon dioxide or GHG (green house gas) emissions, as well as other emissions, energy demand and efficiency, are investigated within such an analysis.

A well-to-wheel analysis can be subdivided into two parts:

a) The well-to-tank (energy provision) and
b) Tank-to-wheel (vehicle efficiency) analysis.

Compared to a life cycle analysis the production, maintenance and disposal of the vehicle are not assessed. In addition, fewer environmental impact categories are taken into account.

Well-to-wheel analysis has varying stages.

1) Well-to-station, the first stage, involves the extraction or production of fuel, and the **“upstream” section,**

2) Station-to-the-wheel is related to how it is consumed and burned, sometimes referred to as the **“downstream” part.**

The well-to-wheel analysis is usually used to assess the overall energy consumption of various transportation vehicles from cars to aircraft (GM, 2001).

Calculating Well-to-Wheel efficiency of electric Vehicles:

A common criticism of electric vehicles regarding emissions is that:

1) The grid power is produced from a variety of means - like hydro, wind, geothermal, nuclear, solar, etc. that involve no CO2 emissions.

2) We work out some calculations to show that electric vehicles, even if powered by electricity generated by coal powered plants are much more efficient than oil based vehicles and as a result release less CO2 emissions.

Direct and Well-to-Wheel Analysis

- Well-to-wheel analysis **include all emissions** related to fuel production, processing, distribution and combustion
- In case of gasoline, emissions are produced while extracting petroleum from the earth, refining it, distributing the fuel to stations, and burning it in vehicles
- In case of electricity, most electric power plants produce emissions, and there are **additional emissions** associated with the extraction, processing, and distribution of the primary energy sources they use for electricity production
- **Batteries - Where it comes from and where it goes**
- **Recycling and final disposal of batteries** and its consequences on the environment is also considered even before manufacturing

Here are some use cases, where we calculate the well-to-wheel efficiency and compare the results in terms of efficiency and CO2 emissions.
A) Small petrol car vs Small electric car
b) Diesel SUV vs Electric SUV
c) Petrol scooter vs electric scooter

A) Small petrol car vs Small electric car
Well-to-Wheel efficiency of a small Indian petrol car
Petrol has a calorific value of 34.3 MJ/liter.
Refinement & transportation losses (about 33% in India)
So a regular petrol car giving 15 km/liter has an efficiency of 1/(34.3 divided by (100% minus 33%)) x 15 km/l = 0.29 km/MJ or 0.29 km/277 Wh
(1/{34.3/{1-.33}})*15=0.29
In other words, to travel a distance of 1 km, a small petrol car must expend **3.45 MJ or 955 Wh** of energy.

Well-to-Wheel efficiency of a small Indian electric car

After observing data from users of the Mahindra e2o electric car, we find that on an average, an electric car in Indian road conditions consumes 90 Wh/km

We know that 1 Wh = 3600 J, so 90 Wh = 324,000 J.

And the power plant efficiency, conversion and transmission losses in electricity in India are 70% or more.

So an Indian electric car @ 90 Wh/km has an efficiency of 1/(3600 divided by (100% minus 70%)) x 10^6 x (1/90) km/Wh = 0.93 km/MJ.

We then multiply this by the "The full cycle charge and discharge efficiency of the electric car". Let us take this factor as 80% for the e2o.

Then the final efficiency is 0.93 x 80% = 0.74 km/MJ or 0.74 km/277 Wh

In other words, to travel a distance of 1 km, a small electric car must expend **1.35 MJ or 375 Wh** of energy.

Verdict

An small electric car is more than 2.5 times efficient than an equivalent petrol car.

Diesel SUV vs Electric SUV

Well-to-Wheel efficiency of a diesel SUV

Diesel has a calorific value of 38.4 MJ/liter.

Refinement & transportation losses (about 33% in India).

Regular diesel SUV giving 10 km/liter has an efficiency of 1/(38.4 divided by (100% minus 33%)) x 10 km/l = 0.17 km/MJ or 0.17 km/277 Wh

In other words, to travel a distance of 1 km, a diesel SUV must expend **5.88 MJ or 1633 Wh** of energy.

Well-to-Wheel efficiency of an electric SUV

After from the official EPA data of the Tesla Model X electric SUV, we know that that it has an efficiency of 237.5 Wh/km

We know that 1 Wh = 3600 J, so 237.5 Wh = 855,000 J. And the power plant efficiency, conversion and transmission losses in electricity in India are 70% or more.

So a Tesla Model X electric SUV @ 237.5 Wh/km has an efficiency of 1/(3600 divided by (100% minus 70%)) x 10^6 x (1/237.5) km/Wh = 0.35 km/MJ.

We then multiply this by the "The full cycle charge and discharge efficiency of the electric car". Let us take this factor as 90% for the Tesla.

Then the final efficiency is 0.35 x 90% = 0.32 km/MJ or 0.32 km/277 Wh

In other words, to travel a distance of 1 km, an electric SUV must expend **3.12 MJ or 867 Wh** of energy.

Verdict

An electric SUV is more than 1.8 times efficient than an equivalent diesel SUV.

Petrol scooter vs Electric scooter
Well-to-Wheel efficiency of a petrol scooter
Petrol has a calorific value of 34.3 MJ/liter.
Refinement & transportation losses (about 33% in India).

So a regular petrol scooter giving 50 km/liter has an efficiency of 1/(34.3 divided by (100% minus 33%)) x 50 km/l = 0.97 km/MJ or 0.97 km/277 Wh

In other words, to travel a distance of 1 km, a petrol scooter must expend **1.03 MJ or 286 Wh** of energy.

Well-to-Wheel efficiency of an electric scooter

After observing data from users of electric bikes like Hero electric, Morello Yamasaki and also getting test data from upcoming e-bikes like Ather S340, we find that on an average, an electric scooter in Indian road conditions consumes 33 Wh/km

And the power plant efficiency , conversion and transmission losses in electricity in India are 70% or more.

So an Indian electric scooter @ 33 Wh/km has an efficiency of 1/(3600 divided by (100% minus 70%)) x 10^6 x (1/33) km/Wh = 2.52 km/MJ.

We then multiply this by the "The full cycle charge efficiency of the electric bike". Let us take this factor as 90% for ebikes.

Then the final efficiency is 2.52 x 90% = 2.26 km/MJ or 2.26 km/277 Wh

In other words, to travel a distance of 1 km, an electric scooter must expend **0.44 MJ or 122 Wh** of energy.

Verdict

An electric scooter is more than 2 times efficient than an equivalent petrol scooter.

Traction Motor

- **Traction motor** refers to a type of **electric motor.** A traction motor is used to make **rotation torque** on a machine

- Traction motors are used in **electrically** powered vehicles such as electric vehicles and electric locomotives

- The traction motor of EVs is responsible for **converting electrical energy to mechanical energy**

Traction Motors and Motor Drivers Used in Electric Vehicles

Electric vehicles act with electric motors using direct current (DC) obtained from the batteries in the vehicle. A very important part of these motors work with DC while others work with the alternative current AC electrical energy obtained at the desired amplitude and frequency with the help of an inverter. These motors are also called electric traction motor (ETM).

Required features in motors used in electric vehicles are high energy efficiency, low cost, high-performance, quick acceleration, stopping and starting numbers, durability to extreme temperatures and vibrations, simply construction, regenerative breaking capacity, long lifetime and low maintenance.

Traction Motors and Motor Drivers Used in Electric Vehicles

Types of electric motors include

1) Brushless DC motor (BLDC),
2) AC induction motor (ACIM),
3) Permanent magnet synchronous motor (PMS),
4) Permanent magnet switched reluctance motor (PMSRM).

In general, the inverter converts AC or DC electrical energy into AC energy suitable for the operation of the electric motor. The inverter adjusts the frequency and amplitude of the alternating current with the help of a microcontroller. The microcontroller evaluates all the parameters related to the vehicle and ensures that the necessary tasks are fulfilled. In this way, it can change the rotating speed, power and torque of the electric motor.

Selection of Traction Motors Used in Electric Vehicles

The most important features of the motors to be used in electric vehicles are:

❖High torque at the time of first movement

❖Low power consumption and efficiency at high speeds that is Good Performance.

❖Know the max voltage, current and load values.

❖Matching of desired characteristics.

❖Suitable mechanical & electrical features

❖Effective speed control.

❖Quick reversal of direction to function as generator.

Characteristics of traction motor
1. Mechanical 2. Electrical

Mechanical Characteristics

- Robustness
  - Must be strong enough to withstand continuous vibration and other forces acting during running of train
- Light Weight
  - High power to weight ratio
  - Lesser the weight of motor, higher the operating efficiency

Mechanical Characteristics

- Totally Enclosed
  - Protects itself against ingress of dirt, dust, mud water etc.
- Overall Size
  - The physical dimension of motor
    - Diameter of driving wheel
    - Width of track gauge
    - Ground clearance
  - Using high speed motor, overall size can be reduced

Electrical Characteristics

- High starting torque
  - Capable of developing high starting torque as train has to start with heavy load and accelerate to maximum speed
- Parallel Running
  - Can be operated in parallel and mechanically coupled so as to share the load almost constant

Electrical Characteristics

- Simple & Easy Speed Control
  - To start & stop frequently, easy, simple & economical speed control is preferred
- Voltage Fluctuation
  - Capable of withstanding voltage fluctuation of supply without affecting its normal performance
- Easy Electric Braking
  - Easy and simple method of dynamic or regenerative braking

Electrical Characteristics

- High Efficiency
  - High mechanical & electrical efficiency so as to improve its performance and reduce running cost

DC Series Motor

DC Compound Motor

3- Phase induction Motor

Traction Motors and Motor Drivers Used in Electric Vehicles

CONCLUSION

The most important features of the motors to be used in electric vehicles are high torque at the time of first movement and low power consumption and good efficiency at high speeds.

These motors are commonly used in start and stop cars so they may be heat up more. Hence, they need good cooling.

The motors commonly used in electric vehicles are BLDC motors. Specially designed electronic circuits are required to start the motors. These circuits are called motor drives. Motor drivers control electric motors by interpreting the accelerator and brake pedal information.

EV vs ICE: Are electric cars worth it?

Internal combustion engine vehicles still make up the majority of car sales. But are the benefits of electric enough to make you switch? We compare the two.
what are the key differences?

1) EVs are more energy efficient

The average Internal Combustion Engine has a fuel efficiency of only 40% – with 60% is lost via heat and friction. As a result, ICEs consume far more energy travelling the same distance as an EV.

2) EVs Are Smoother To Run

EVs are well known for running smoothly and silently. Using an electric engine instead of an exhaust system, they naturally operate with less noise pollution and have a smoother acceleration and deceleration.
On top of this, their lower centre of gravity provides better handling, comfort and responsiveness. EVs also tend to use less energy in stop-and-go city traffic.

EV vs ICE: Are electric cars worth it?

3) EVs tend to have lower maintenance costs

The relatively high initial outlay cost of buying an EV can be offset by reduced costs in other areas such as maintenance. EVs have far less moving parts and therefore cost less to maintain, and experience less wear and tear.

That being said, EVs do still require some maintenance. Brakes, Tyres and other consumables should be inspected periodically, in line with manufacturer's instructions. These inspection schedules tend to occur less frequently than combustion engine vehicles as EVs are lighter on tyres and brakes due to the effect of regenerative braking.

Most EVs can be supported by main dealerships. However, independent service centres equipped to service EVs are currently few and far between.

4) **Electricity is cheaper than petrol**

It's much cheaper to fuel your car with electricity versus petrol in the UK. Especially as you can charge your car at home – and install solar panels to generate your own electricity if you wish. Electric cars are even capable of turning into generators and creating their own energy through regenerative braking (using the energy expanded when slowing the vehicle to recharge).

EV vs ICE: Are electric cars worth it?

5) It's better for the environment

Transport is responsible for 34% of C02 emissions in the UK, with the large majority coming from road transport specifically. Yes, there is still an environmental cost of the production of EVs but these vehicles don't emit CO_2 or greenhouse gases and so their lifetime carbon footprint is much lower. For example, a recent Reuters study found that a Tesla Model 3 would need to be driven for 13,500 miles (21,725 km) before it does less harm to the environment than a Toyota Corolla.

Prolonging life and reducing negative health impacts are another bonus. Thousands of people with health conditions (such as asthma) stand to benefit from the cleaner air. One study China suggested 17,500 deaths could be prevented if just over a quarter of privately owned cars and a slightly larger share of commercial vehicles were electric.

ELECTRICAL DRIVES: PERFORMANCE

Performance

When it comes to electric vehicles: driving is believing.

Meet today's electric vehicles

If you still believe that electric vehicles aren't real cars, then you should look again. EV's look good, feel good and exhibit performance like few others. They combine fun and function.

Smooth running

An EV won't jolt you as you progress from first to sixth gear. Instead, a squeeze on the accelerator will effortlessly take you up to your desired speed. The automatic transmission means that the rate of change of speed is almost linear. So you can give your clutch foot a rest.

Superior interior trim

The interior of an EV often catches the eye of first time browsers. Car companies seem to be aiming for a discerning owner with options from leather and chrome to wood. High quality fabrics or leather trims are available in most EV's.

Highly specified for electronics

Electric vehicles often come with a very high electronics specification as standard. This may include advanced cruise control, SatNav and bluetooth. Charging timers allow you to tap into cheaper night rate electricity. Finally, heated seating and steering wheels are also frequently offered.

Connected

Many of the electric vehicles on the market offer a smartphone app so you can access them remotely. Apps can offer a number of functions, depending on your car:

- Updates on the vehicle's charge status
- Start or stop the charge when plugged into your home charge point
- Remote heating and comfort control to allow preheating before you use the car
- Manage your heating and charging schedule

Instant acceleration

While we all need to stick to safe driving speeds, it is good to know that when we need acceleration, it is ready. The electric motor drive means an electric vehicle's response to acceleration is up there with the best. You have almost instant access to power, with no loss. Compare this to other transmissions as you change from gear to gear.

Intelligent regeneration

Using our brakes to slow down for traffic lights and stop signs creates much of the energy loss in our vehicles. Electric vehicles reduce this loss by using the motor to slow down the car when you take your foot off the accelerator. The energy is sent back into the battery, in turn allowing an increased driving range. Many electric vehicles allow the driver to adjust the regeneration effect to suit their driving style.

HYBRID ELECTRIC DRIVE TRAINS

The term hybrid vehicle refers to a vehicle with at least two sources of power

(i) one source of power is provided by an electric motor.

(ii) Second source, typically provided by an IC engine

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

A hybrid vehicle combines any two power generating sources. Many combinations such as diesel/electric, gasoline / fly wheel, and fuel cell (FC) / battery are usually used. Typically, one energy source is storage, and the other converts a fuel to energy. The combination of two power sources can support two separate propulsion systems or combine into a single propulsion system.

CLASSIFICATION OF HEVS

A. <u>Based on Architecture:</u>

1) Series Configuration:

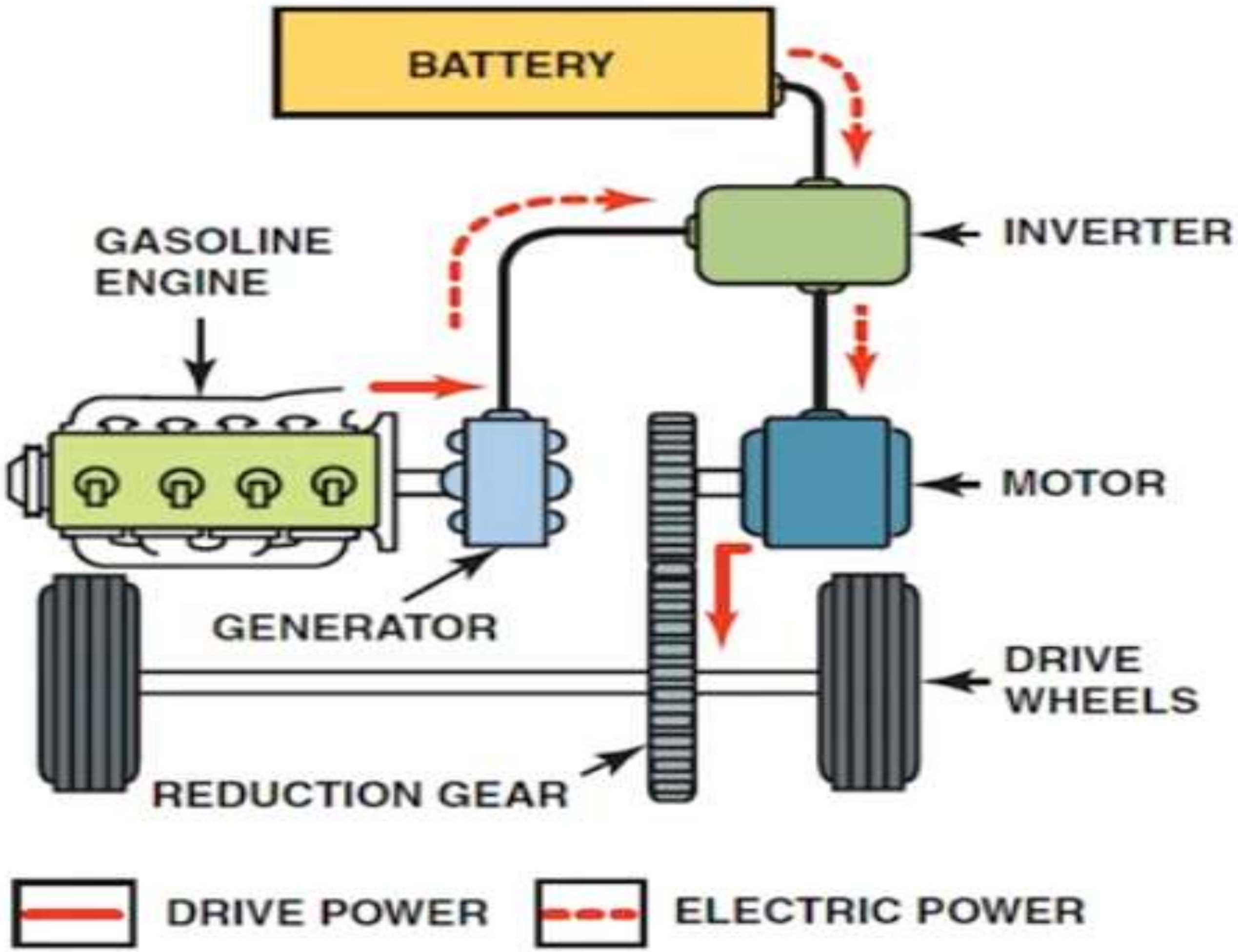
A series is one in which only one energy converter can provide propulsion power. IC engine acts as a prime mover. The power required to propel the vehicle is provided solely by the electric motor.

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

2. *Parallel* Configuration: A parallel hybrid is one in which more than one conversion device can deliver propulsion power to the wheels . In parallel HEV, the power requirements of the electric motor are lower than electric vehicle as IC engine complements total power demand of the vehicle.

3. ***Series-Parallel Hybrid (Split Type):*** In S-P hybrids, the IC engine is also used to charge the battery. S-P HEV is basically series HEV but with a small series element added to the architecture. It ensures that the battery charge is sustained in prolonged wait periods in traffic jams.

Series Hybrid Vehicle



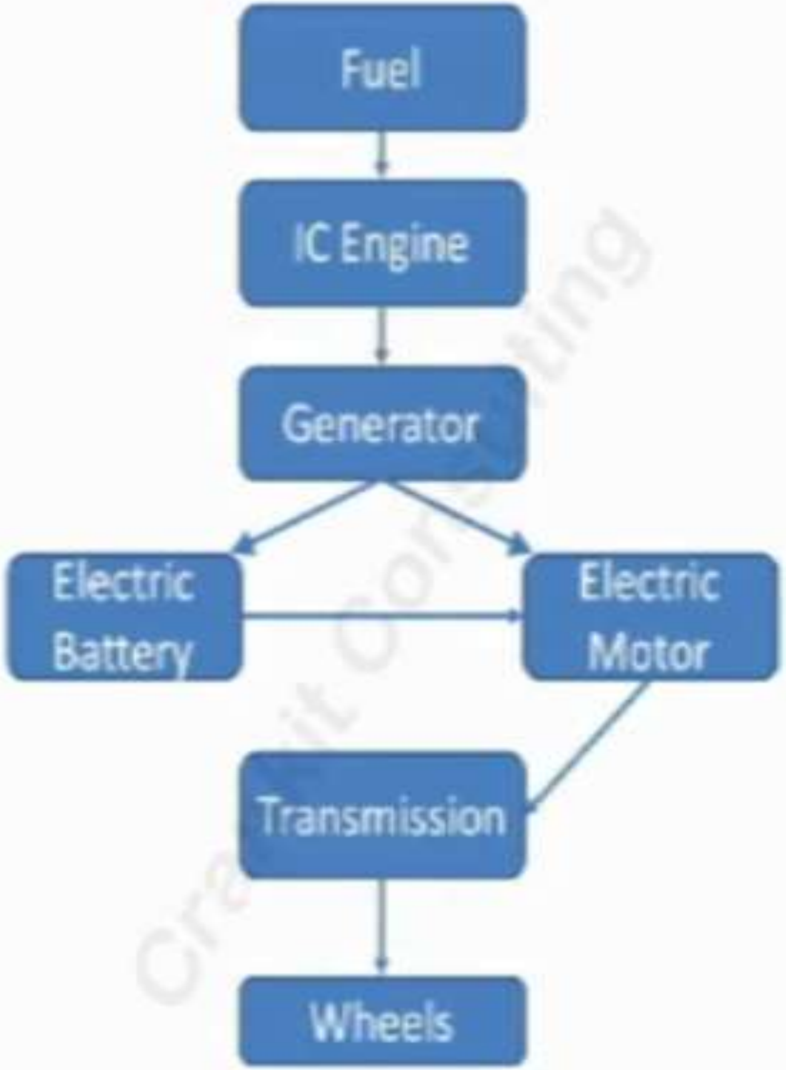
- **Series hybrid is to couple the ICE with the generator to produce electricity for pure electric propulsion**
- **Mechanical output is first converted into electricity using a generator.**
- **Converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission.**
- **Conceptually, it is an ICE assisted Electric Vehicle (EV).**

1. Series Hybrid

In this type of hybrid vehicle, wheels are powered only by an Electric motor which ultimately derives its power from the electric battery. The IC engine installed in the vehicle does not supply power to wheels directly. So, these vehicles need large capacity batteries.

The series hybrid vehicle is more efficient in low-speed driving involving frequent start-stop.

A series hybrid is like a Battery Electric Vehicle (BEV) in design. Here, the combustion engine drives an electric generator instead of directly driving the wheels.

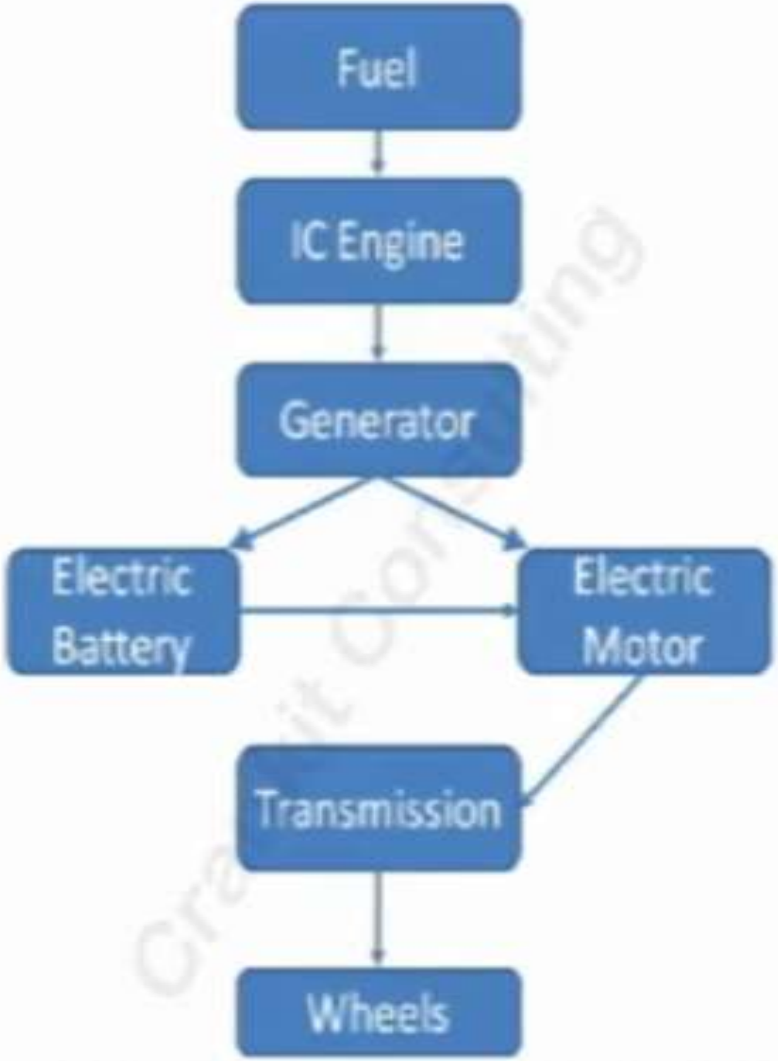


Schematic of a Series hybrid

1. Series Hybrid

The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the battery and the generator.

Series hybrids may also be referred to as Extended-Range Electric Vehicles (EREVs) or Range-Extended Electric Vehicles (REEVs) since the gas engine only generates electricity to be used by the electric motor and never directly drives the wheels.



Schematic of a Series hybrid

Advantages

- No Transmission
- No clutch
- No torque converter
- Mechanical decoupling between the ICE and wheels allows IC engine operation at optimal
- Nearly ideal torque-speed characteristics of electric motor make multi-gear transmission unnecessary

Dis-advantages

- Energy is converted twice (mechanical to electrical and then to mechanical) and this reduces the overall efficiency

- Two electric machines are needed and a big motor is required because it is the only torque source of the driven wheels

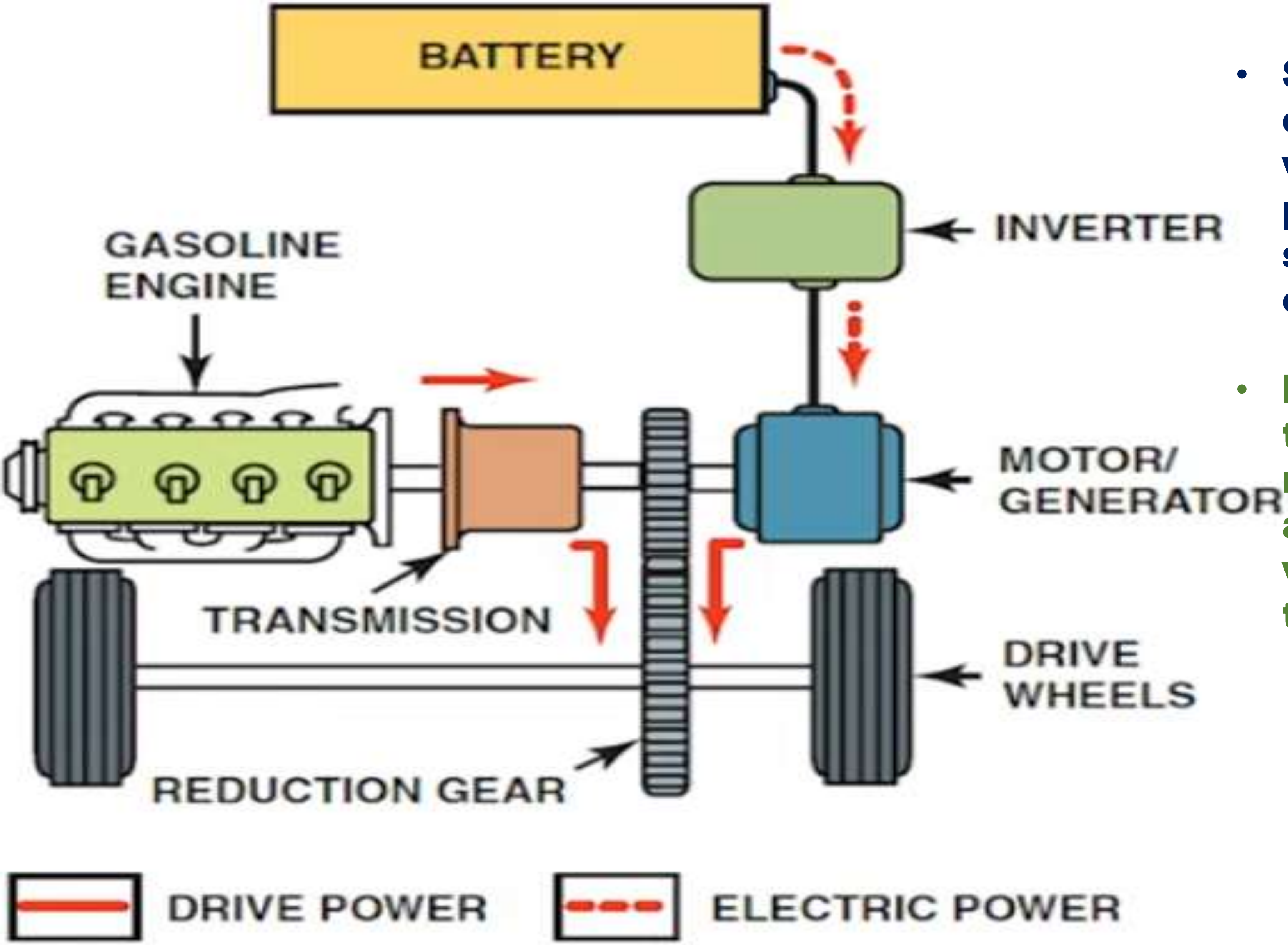
- Completely dependent on battery power

Application: heavy commercial vehicles, military vehicles and buses.

Reason: large vehicles have space for the bulky engine/generator system

To tackle this problem.....

Parallel Hybrid Vehicle

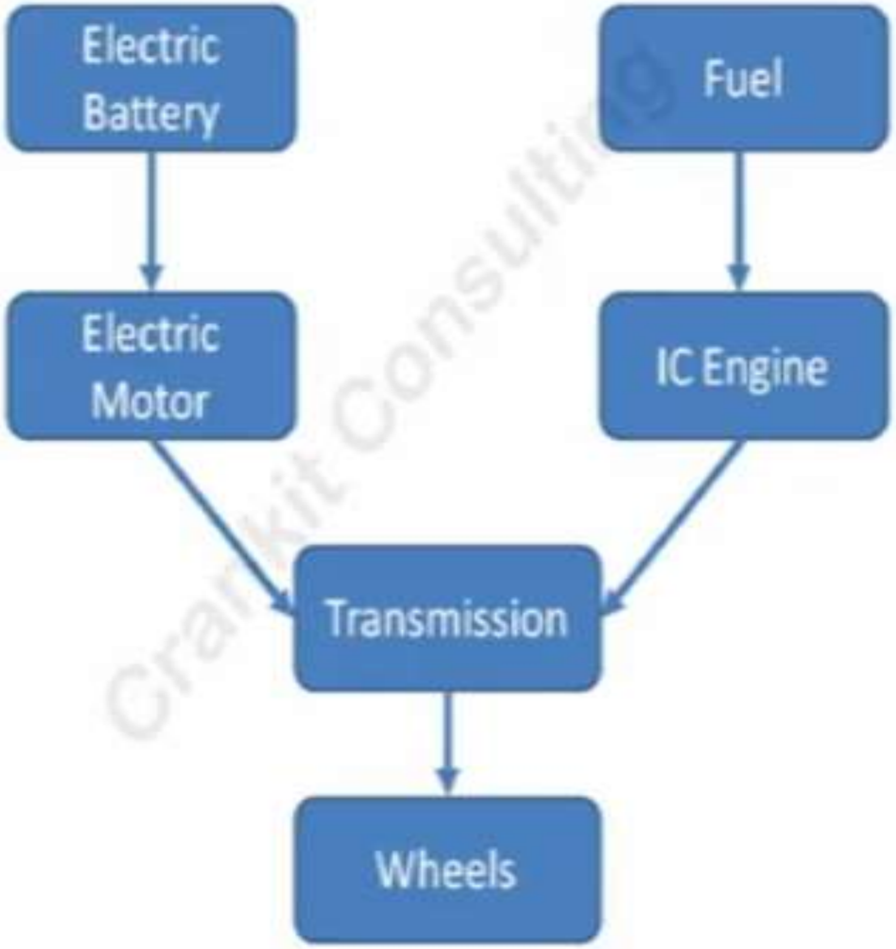


- **Allows both ICE and Electric Motor (EM) to deliver power to drive the wheels**
- **Since both the ICE and EM are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM**
- **EM can be used as a generator to charge the battery by regenerative braking or absorbing power from the ICE when its output is greater than that required to drive the wheels.**

2. Parallel Hybrid

In this type of a hybrid vehicle, wheels get power from both the IC engine and an Electric Motor. The drivetrain of these vehicles is so designed that it can receive power from both the IC engine and Battery simultaneously. However, the IC engine serves as the main source of power in the Parallel hybrid vehicle.

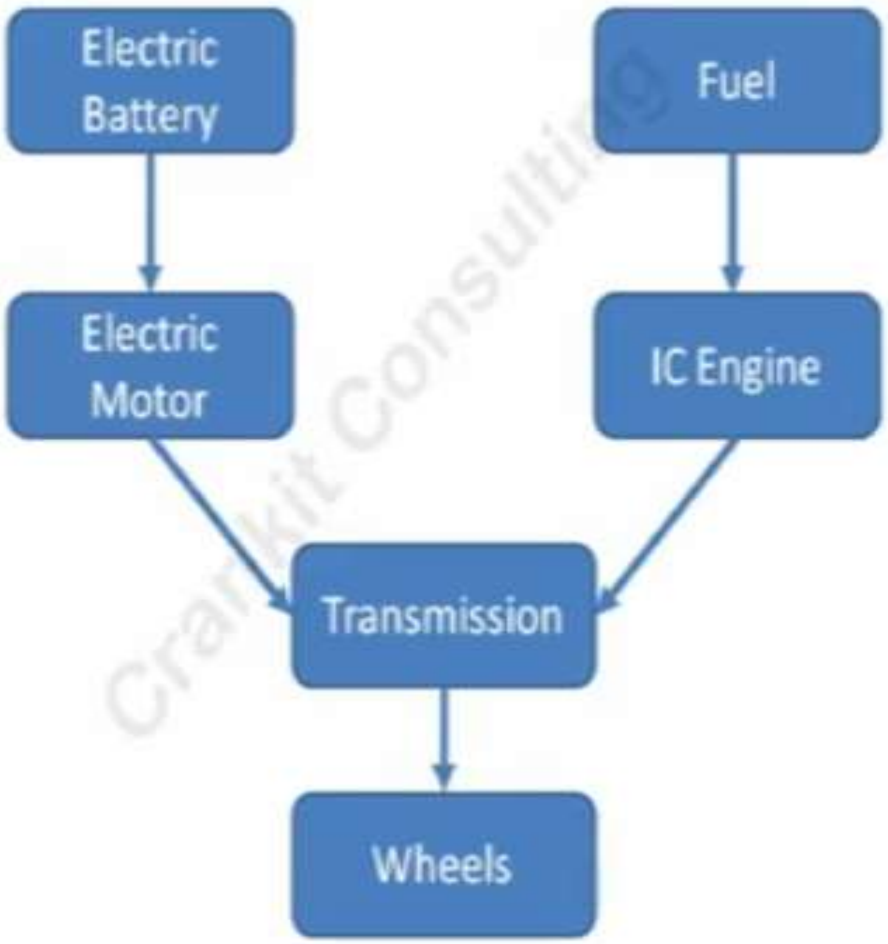
As electric battery's role is only to support the engine, these vehicles need a smaller capacity battery. A parallel hybrid is more effective in high-speed driving.



Schematic of a Parallel hybrid

2. Parallel Hybrid

There is no separate generator in a parallel hybrid. Whenever the generator's operation is needed, the motor functions as a generator. In a parallel mild hybrid, the vehicle can never drive in pure electric mode. The electric motor turns on only when a boost is needed.



Schematic of a Parallel hybrid

Advantages

- **Both engine and electric motor directly supply torques to the driven wheels and no energy form conversion occurs**
- **Compactness due to no both energy sources work in tandem leading to significantly less weight**

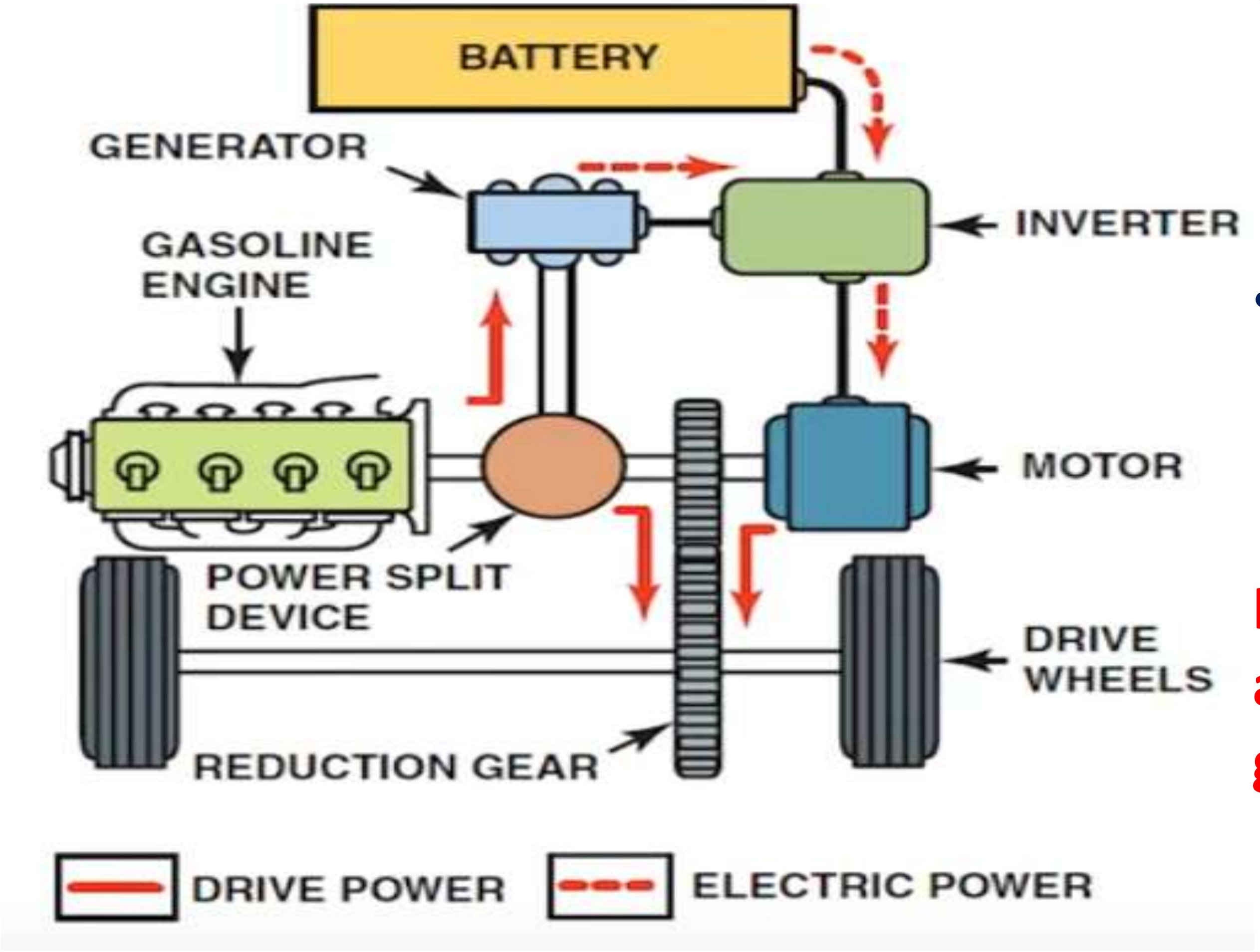
Dis-Advantages

- **Mechanical coupling between the engine and wheels, thus the engine operating points cannot be fixed in a narrow speed region**
- **Mechanical configuration and the control strategy are complex compared to series hybrid drive train as seamless blending of energy from dual sources resulting in complex software and hardwares**

Application: Due to its compact characteristics, small vehicles use parallel configuration.

Most passenger cars employ this configuration.

Series-Parallel Hybrid



- In the series-parallel hybrid (Figure), the configuration incorporates the features of both the series and parallel HEVs

- IC Engine is used to charge the battery as well as drive the wheels resulting in higher efficiency and performance.

However, this configuration needs an additional electric machine and a planetary gear unit making the control complex.

3. Series-Parallel Hybrid/ Power split Hybrid

This recently developed system is a combination of a series hybrid system and parallel hybrid system. Thus, it takes the best from both the worlds. Depending upon the load on the vehicle, it can act like a parallel hybrid vehicle or a series hybrid vehicle. The control module governs the selection of the most suitable mode.

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

B. Based on Degree of Hybridization:

1. Micro Hybrid:

- Electric motor functions to start or stop the system to automatically shut off the engine while idling.
- This motor does not provide additional torque to the vehicle.
- Electric Motor supplies power 2.5kW at 12 volts.
- Energy saving 5 to 10%. Example: BMW 1 series

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

B. Based on Degree of Hybridization:

2. *Mild Hybrid*

- Electric motor generator is integrated to provide 10% of maximum engine power.
- Electric Motor supplies power 10 to 20 kW at 100-200 volts.
- Energy saving is 20 to 30%. Examples: Chevrolet Malibu, Chevrolet Silveradois a full-size pickup truck, Honda Escape, etc.

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

B. Based on Degree of Hybridization:

3. *Full Hybrid:*

- Electric motor provides at least 40% of engine power as additional torque.
- It has improved fuel consumptions and reduced emissions. Circa Electric Motor supplies power 50 kW at 200-300 volts. Energy saving 30 to 50%.
- Example: -Toyota Prius, Ford Fusion Hybrid/Lincoln MKZ Hybrid, Kia Optima Hybrid, as well as the General Motors hybrid trucks.

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

B. Based on Degree of Hybridization:

4. *Plug-in Hybrid:*

- Plug-in hybrid electric vehicles–known as PHEVs–combine a gasoline or diesel engine with an electric motor and a large rechargeable battery. Unlike conventional hybrids, these hybrids can be plugged-in and recharged from an outlet, allowing the vehicle to drive extended distances using just electricity. When the battery is emptied, the conventional engine turns on and the vehicle operates as a conventional, non-plug-in hybrid. Example: Chevrolet Volt, Mitsubishi Outlander P-HEV, Toyota Prius P-HEV, etc.

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

C. **Nature of power source**

1) **Electric-IC engine hybrid**

Electric-IC engine hybrid can be created in many ways. variety of designs differentiate upon how electric motor and combustion engine power train are connected (Series, parallel, series-parallel), what percent of power is produced by electric motor and IC engine, the time at which both portions operate.

CLASSIFICATION OF HYBRID ELECTRIC VEHICLES.

C. Nature of power source

2) Fuel Cells

First successful fuel cells were designed by Francis Bacon in 1932 (designed alkaline fuel cell system with porous electrodes). Main source of energy is hydrogen. They need ultra-capacitor to increase power density required to start the vehicle. They have high energy efficiency. Use of hydrogen results in low use of crude oil as vehicular fuel and low carbon emissions as well .

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