18/03/24 UNIT- 4 - Internal Combustion Engines (IC engines)

→ Any type of engine which derives heat energy from combustion of fuel & converts into mech. work is called heat engine.

E.C. — combustion outside engine

I.C. — combustion of fuel ~~takes~~ inside engine

Adv
1) simple
2) Efficient

(6M)

Classification of IC engines

1. Nature of Thermodynamic cycle
   - Otto cycle engine - Petrol 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 (S.I)
- Compression Ignition engine (C.I)

5. Number of cylinder as-

- Single cylinder engine
- multicylinder engine

6. Position of the cylinder

- Horizontal engine
- Vertical engine
- Radial engine
- In-line engine

7. method of cooling

- Air cooled engine
- water cooled engine

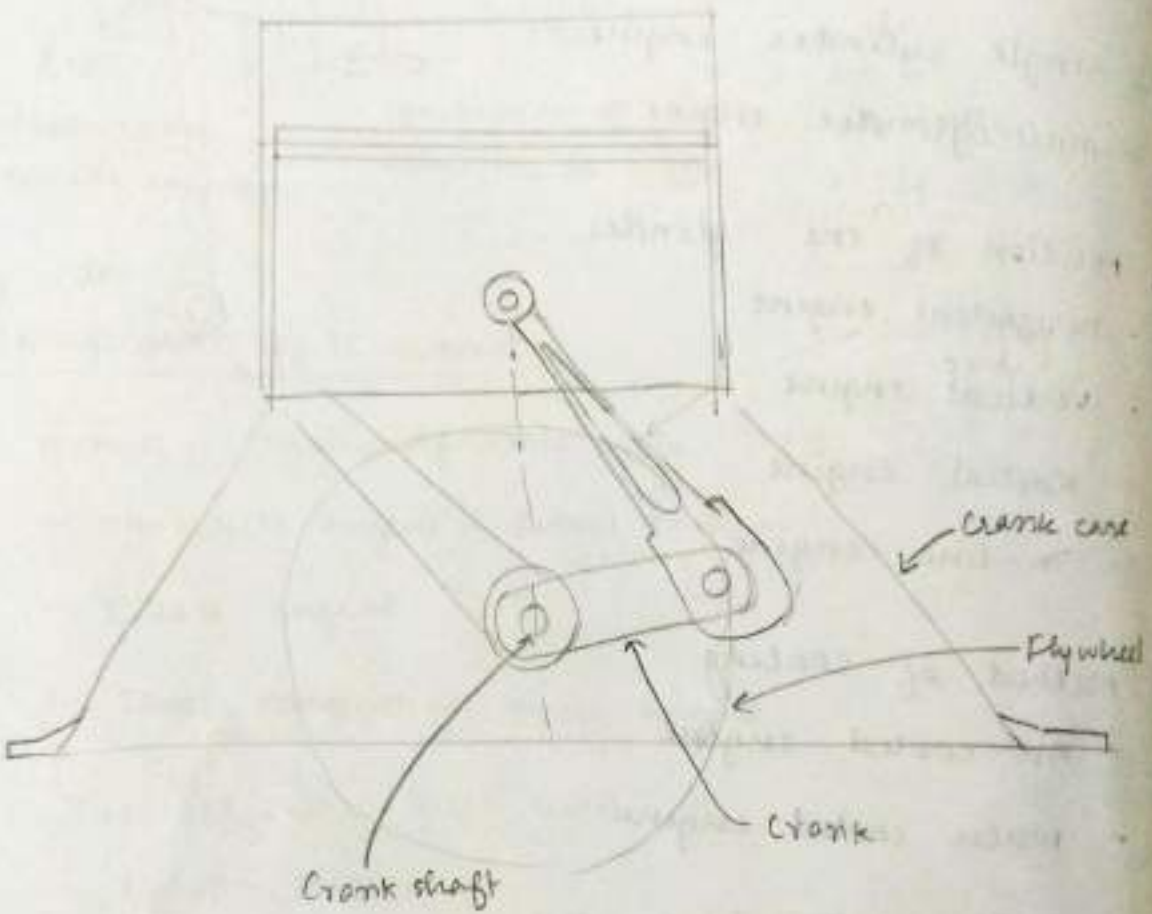
controlled by valve
Through inlet, petrol ~~+ diesel~~ + air mix comes to cylinder.

Piston moves up & down, connecting rod & crank pin & shaft.

Linear motion is conv. to rotary motion of crankshaft by con. rod & crank pin.

controlled by cam design
opening & closing of valve

Parts of IC engine (8M)|(10M)



① Cylinder:

→ made of grey cast iron. → absorbs heat & transfers outside

→ To avoid wear & tear, cylinder liners are provided → rubber liners

→ Fins are present outside the cylinder to dissipate the heat (∵ SA is ↑ed) produced inside. at a faster rate.

② Cylinder - head:

→ Consists of inlet and outlet exhaust walls/ openings.

③ Piston:

→ hollow cylindrical plunger moving to & fro inside the
↳ to make it lightweight
cylinder and made of alluminium alloys

→ Power developed by combustion of fuel is transmitted by piston to crank shaft through the connecting rod by crank pin.

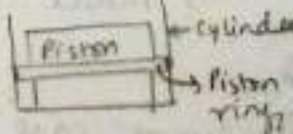
④ Piston rings:

→ metallic rings made of cast iron.

→ piston rings maintain a gas-tight seal between cylinder and piston.

→ also help in conducting heat from piston to cylinder

→ They are in contact with cylinder, not piston.



⑤ Connecting Rod:

→ made up of alloy steels

→ help in converting linear motion of piston into rotary motion of crankshaft with the help of crank pin.

⑥ Crank & Crankshaft:

→ Crank is a lever made of carbon-steel, connected to end of connecting rod by a pin joint.

→ The other end of the crank is rigidly connected to a shaft known as crankshaft.

⑦ Inlet & Outlet Valves:

→ They control opening and closing of the inlet and the outlet.

→ A.k.a "Poppet Valves".

→ Working of Poppet valves is controlled by cam mechanism.

⑧ Flywheel

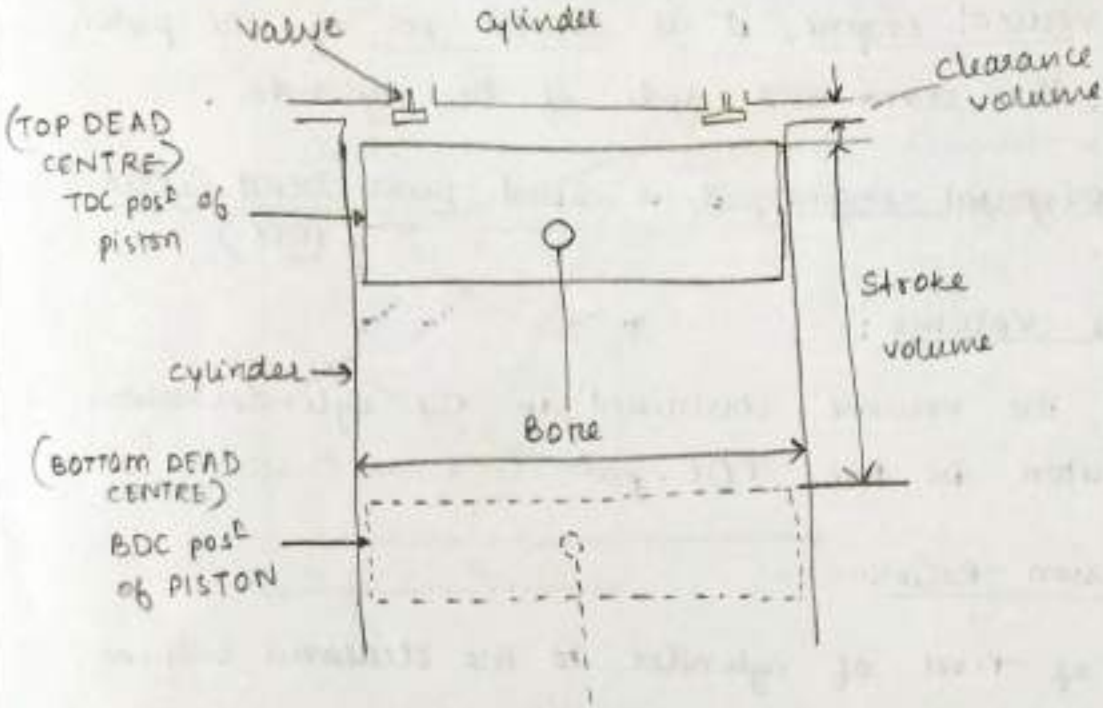
→ mounted on the crankshaft to maintain uniform rotation of the crankshaft.

→ made of cast-iron.

⑨ Crank case:

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

IC Engine Terminology



① **Bore**:

→ Inner diameter of engine cylinder

② **Stroke**:

from TDC → BDC

→ distance travelled by the piston from one end of the cylinder to the other end.

→ twice the radius of crank.

③ **TDC**:

→ In vertical engine, it is the top-most posⁿ of the piston towards the cover side of the cylinder.

→ In horizontal engine, it is called the Inner Dead Centre (IDC)

Crank rad.:

Dist b/w shaft centre & crank pin

(4) BDC :

→ In a vertical engine, it is lowest posⁿ of the piston towards the crank end side of the cylinder.

→ In horizontal engine, it is called Outer Dead Centre (ODC)

(5) Clearance Volume :

→ It is the volume contained in the cylinder above the piston in the TDC. posⁿ.

**

(6) Compression Ratio :

(1M)

→ Ratio of T. Vol of cylinder to the clearance volume

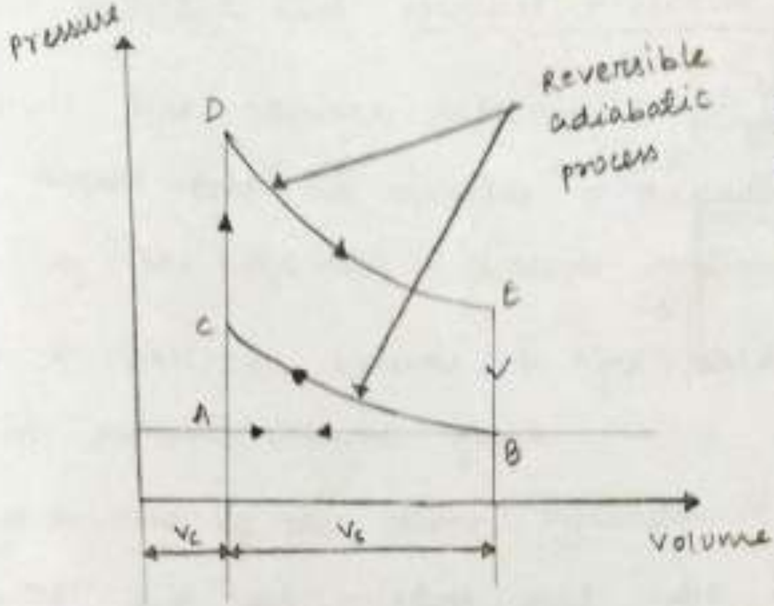
If V_c = clearance volume

V_s = swept volume of piston

$$\boxed{\text{compression ratio} = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c}}$$

As $\boxed{V_s > V_c}$, compression ratio is above unity.

FOUR STROKE CYCLE PETROL ENGINE



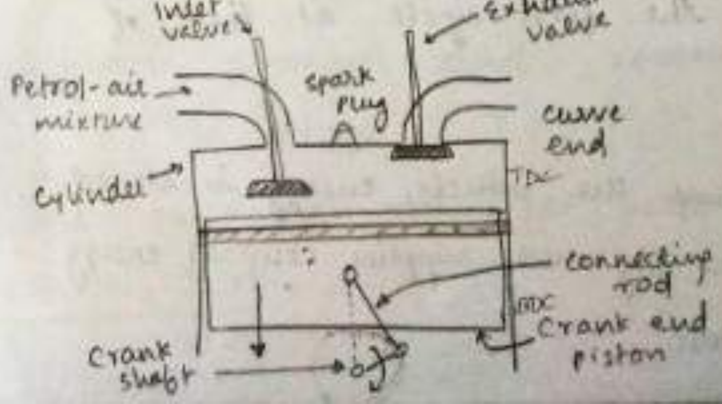
Pressure- volume Diagram of Otto cycle.

→ Petrol engine works on the principle of theoreticle Otto cycle (petrol engine)
a.k.a. Constant volume cycle.

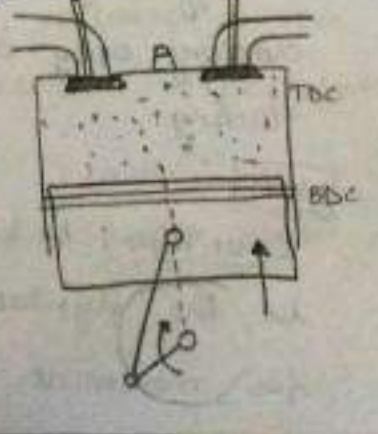
→ This engine has 4 strokes:

- SUCTION stroke
- COMPRESSION stroke
- WORKING (OR) POWER stroke
- EXHAUST STROKE

→ SUCTION Stroke:

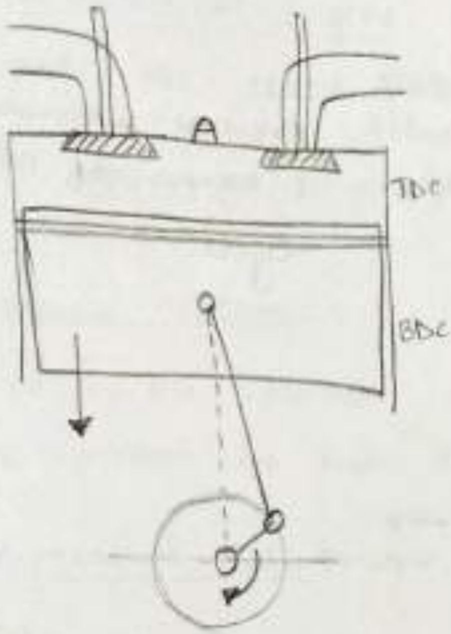


→ COMPRESSION Stroke:



→ POWER stroke:

→ EXHAUST stroke:



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FOUR STROKE PETROL ENGINE

→ works on theoretical Otto cycle aka Constant Volume Cycle

* Suction Stroke:

→ Inlet is open and ~~exhaust~~ outlet is closed.

→ Piston moves from TDC to BDC.

→ Crankshaft revolves by half-rotation.

→ Energy req. to perform this stroke is supplied by cranking only during the first cycle at time of starting.

NOTE

Cranking: By kickstarting the vehicle, energy is stored in the flywheel. This flywheel supplies constant energy for movement of piston.

**

→ As the piston moves from TDC to BDC, volume in the cylinder increases and pressure decreases.

** → Due to this pressure difference with atmospheric pressure, fresh petrol and air mixture is admitted into the top portion of the cylinder through carburetor.

→ This increase in volume is represented by the curve AB in pressure-volume graph.

→ At the end of this stroke, cylinder is completely filled by petrol and air mixture and inlet is closed by inlet valve.

Compression Stroke: (S.I engine)

→ Inlet and outlet are closed.

→ Piston moves from BDC to TDC.

→ Crankshaft revolves by half rotation.

→ Energy req for movement of piston is supplied by the cranking process only during the 1st cycle.

→ As piston moves from BDC to TDC, volume in the cylinder decreases and pressure increases repereesented by BC in graph.

→ The compression ratio for petrol engine ranges from 1:7 to 1:11.

→ At the end of this stroke, petrol & air mixture is ignited by spark plug and hence this type of engine is aka Spark ignition engine, or S.I. engine.

→ Combustion of petrol releases hot gases which will increase the pressure at constant volume represented by vertical line CD in the graph.

Working / Power Stroke:

→ Inlet and outlet are closed.

→ Piston moves from TDC to BDC.

→ Crankshaft revolves by half-rotation.

→ The high pressure burnt gases forced the piston to perform this stroke called as working / Power stroke.

→ Linear motion of the piston is converted into rotary motion of crankshaft by connecting rod & crankpin.

→ As piston moves towards BDC, pressure decreases reperesented by DE in the graph.

→ At the end of this stroke, exhaust opens which releases the burnt gases to the atmosphere and there will be a sudden drop in pressure reperesented by EB in the graph.

Exhaust Stroke :

→ Inlet is closed and outlet is open

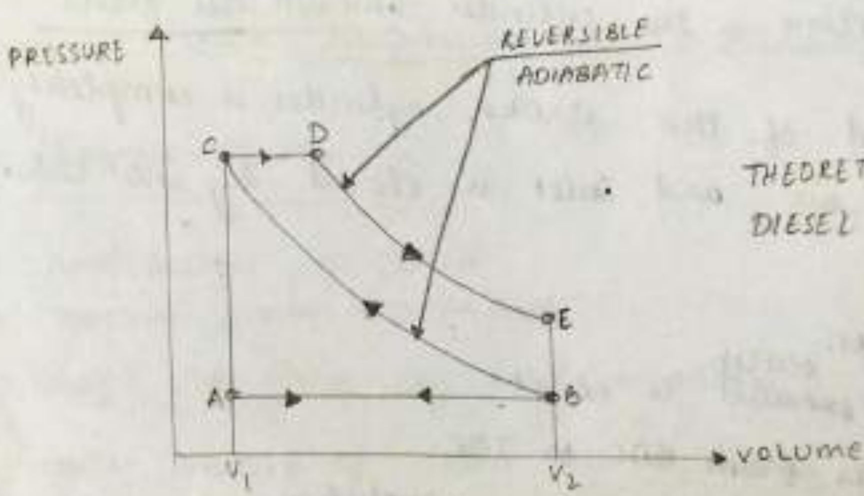
→ Piston moves from BDC to TDC

→ Crankshaft revolves by half-rotation

*(Total 2 rotations occur in the crankshaft)

→ As piston moves from BDC to TDC, the burnt gases will be expelled out of the cylinder at atmospheric pressure represented by BA in the graph.

FOUR STROKE DIESEL ENGINE



THEORETICAL DIESEL ENGINE

→ The diesel engine works on the principle of theoretical Diesel cycle aka Constant Pressure heat addition cycle.

SUCTION STROKE :

→ Inlet is open and outlet is closed.

→ Piston moves from TDC to BDC

→ Crankshaft revolves by half-rotation

→ Energy req for movement of piston is provided by the cranking process.

→ As the piston moves from TDC to BDC, volume increases pressure decreases rep. by AB as in graph.

→ As the pressure decreases, a pressure diff. is created b/w cylinder & atm pressure.

→ Due to this pressure diff., fresh atm air is admitted in the top portion of the cylinder through air filter.

→ At the end of this stroke, cylinder is completely filled by atm air and inlet is closed by inlet valve.

Compression Stroke:

→ Inlet and ~~exhaust~~ outlet is closed.

→ Piston moves from BDC to TDC.

→ Crankshaft revolves by half-revolution.

→ Energy req. is supplied by cranking process only during the 1st cycle

→ As piston moves from BDC to TDC, the compression ratio ranges from 1:20 to 1:22 rep by curve BC on the graph.

* The compression ratio in this engine is higher than the 4-stroke petrol engine as the air is compressed to a higher compression ratio, temperature of the compressed air increases and will attain a temperature greater than the ignition temperature of a diesel oil.

NOTE

Ignition Temp of Petrol & Diesel Oil:

→ At the end of this stroke, a metered (measured) qty of the diesel oil is spread into the cylinder through a fuel injector.

→ * The high temperature of air ignites the diesel ~~engine~~ oil as soon as it is sprayed (greater SA (small droplets)). Called auto/self-ignition.

→ This engine aka compression ignition engine or C.I. engine.

Working / Power stroke:

→ Inlet and outlet is closed.
→ Piston moves from TDC → BDC
→ Crankshaft revolves by half rotation.
→ The auto-ignition of diesel oil initiates the combustion, as a result the hot gases are released which force the piston to move from TDC to BDC at const pressure
→ This const pressure expansion with simultaneous combustion is rep. theoretically by line CD in PV graph.

→ The linear motion of piston is converted into rotary motion of crankshaft through connecting rod and crankpin

→ As the piston moves from TDC → BDC, pressure ↓es rep by DE in the P-V graph.

→ At the end of this stroke, exhaust valve opens and the burnt gases are released to the atmosphere and there is a sudden drop in the pressure rep. by the curve EB on the P-V graph.

Exhaust Stroke:

→ ~~Bas~~ Inlet closed and outlet opened
→ Piston moves from BDC to TDC.
→ Crankshaft revolves half revolution
⇒ [* Total 2 rotation of crankshaft]

→ As piston moves from BDC → TDC, the burnt gases will be expelled out of the cylinder

→ Volume decreases, which is rep. by BA on P-V graph.

A-2
1) Adv & Disadv. of 4 stroke i) Petrol ii) Diesel Engine
2) Compare b/w 4 stroke petrol & diesel engine
3) EV v/s ICE
5) Parallel - Hybrid vehicle
6) Series - Parallel Hybrid
4) Series - Hybrid Vehicle diagram (pg 82)

* Specific Fuel Consumption

→ It is defined as the amount of fuel consumed by an engine for 1 unit of energy produced and is used to express the fuel efficiency of an IC engine and is expressed in kg/MJ or kg/kW-h

* Indicated Power

→ It is the power produced inside the cylinder.

→ a = area of actual indicator diagram (cm^2)

l = base width of indicator diagram (cm)

s = spring value of spring used in indicator $N/m^2/cm$

If P_m = Actual mean effective pressure (N/m^2)

$$\boxed{P_m = \frac{sa}{l} \; N/m^2}$$

* Indicated Power of Four Stroke Engine

P_m = mean effective pressure (N/m^2)

L = length of stroke (m)

A = area of cross-section (m^2)

N = RPM of crankshaft

n = no. of cycles per minute

$$\text{work produced by piston/stroke or cycle} = \left|\begin{matrix}\text{mean force} \\ \text{acting} \\ \text{on piston}\end{matrix}\right| \times \left|\begin{matrix}\text{piston displacement} \\ \text{in} \\ \text{one stroke}\end{matrix}\right|$$

$$= P_m \times A \times L \ Nm$$

$$= P_m L A \ Nm$$

$$\text{Work produced by piston/minute} = \left|\begin{matrix}\text{work produced} \\ \text{by piston/cycle}\end{matrix}\right| \times \left|\begin{matrix}\text{Number of} \\ \text{cycles per} \\ \text{min}\end{matrix}\right|$$

$$= P_m L A \times n$$

$$= P_m L A n \ Nm/min$$

* In 4-stroke IC engine, 1 cycle will be completed in 2 rev. of the crankshaft. Thus, no. of cycles per min. will be equal to half no. of rev. per min.

$$\boxed{n = \frac{N}{2}}$$

$$\boxed{\text{work produced by piston/min} = P_m L A \frac{N}{2} \ Nm/min}$$

$$\text{Indicated Power} = \frac{P_m L A N}{60 \times 2} \text{ Nm/sec or J/sec}$$

$$= \frac{P_m L A N}{60 \times 2} \text{ W}$$

$$= \frac{P_m L A N}{60 \times 2 \times 1000} \text{ kW}$$

* when P_m is expressed in N/m^2

$$\boxed{\text{Indicated Power} = \frac{P_0 L A N}{60 \times 2 \times 1000} \text{ kW}}$$

* when P_m is expressed in bar

$$\boxed{\text{Indicated Power} = \frac{100 P_m L A N}{60 \times 2} \text{ kW}}$$

Brake Power

→ The indicated power produced inside the I.C engine cylinder which will be transmitted through the piston, connecting rod and crank pin.

→ As these mechanical parts are moving relative to each other, they encounter friction and there will be power loss due to this friction.

* → The net power available at the crank shaft is measured by applying the brake & therefore called brake power.

$$\boxed{\text{Friction Power} = \text{Indicated Power} - \text{Brake Power}}$$

Let W = net load acting on brake drum (kg)

R = radius of brake drum (m)

N = RPM of crankshaft

T = Torque applied due to net load (W) on brake drum (kNm)

$$\boxed{T = W \times R}$$

$$\boxed{\text{Torque},\ T = \frac{9.81}{1000} WR \ \text{kNm}}$$

$$\boxed{\text{Brake Power} = \frac{2\pi NT}{60} \ \text{kW}}$$

Mechanical Efficiency

→ Efficiency of moving parts of the mechanism transmitting indicated power to the crankshaft.

$$\boxed{\eta_{mech} = \frac{\text{Brake Power}}{\text{Indicated Power}} \times 100}$$

$$= \frac{\text{Indicated P} - \text{Friction P}}{\text{Indicated P}} \times 100$$

$$= \frac{BP}{BP + FB} \times 100$$

Thermal Efficiency

→ Defined as the ratio of power developed by engine to the heat supplied by fuel in same interval of time.

$$\eta_{thermal} = \frac{\text{Power Output}}{\text{Heat Energy supplied by fuel}} \times 100$$

Power : may be BP or IP accordingly its called BTE or ITE

→ Brake Thermal Efficiency (BTE) is defined as ratio of brake power to heat supplied by fuel.

$$\eta_{B\ Thermal} = \frac{BP}{\text{H.E. supplied by fuel}} \times 100$$

$$\boxed{\eta_{B\ Thermal} = \frac{BP}{CV \times m} \times 100}$$

m = mass of fuel supplied (kg/s)

CV = Calorific value of fuel (kJ/kg)

BP = Brake power (kW)

→ Indicated Thermal Efficiency (ITE) is defined as a ratio of IP to heat supplied by the fuel.

$$\eta_{I\ Thermal} = \frac{IP}{\text{HE supplied by fuel}} \times 100$$

$$\boxed{\eta_{I\ Thermal} = \frac{IP}{CV \times m} \times 100}$$

Q1) A single cylinder 4 stroke IC engine has a piston diameter of ~~1.05~~ 105 mm and stroke length 120 mm. The $P_m = 6$ bar. If crankshaft speed is 1500 rpm, calc. IP of engine.

$D = 105$ mm $\quad L = 120$ mm $\quad P_m = 6$ bar $\quad N = 1500$ rpm

$$A = \frac{\pi D^2}{4} = 8654.625 \times 10^{-6}\ m^2$$

$$IP = \frac{100\ P_m L A N}{60 \times 2}\ kW$$

$$= \frac{100 \times 6 \times \cancel{120} \times 10^{-3} \times 8654.625 \times 10^{-6} \times 1500}{\cancel{60} \times \cancel{2}}\ kW$$

$$= 778916.25 \times 10^{-5}$$

$$= \underline{7.789\ kW}$$

ELECTRICAL DRIVES

→ run on battery

→ EV uses one or more electric motors for propulsion.

~~⇒ can be powered by~~

Well-to-Wheel Analysis

→ It is a non-standardized method to quantify the impact of transportation of fuels & vehicles regarding energy and climate change.

→ This analysis can be sub-divided into 2 parts:

a) Well to Tank (energy provision)

b) Tank to Wheel (vehicle efficiency) analysis.

Well-to-Wheel Efficiency

1) small Petrol car vs small electric car

small Petrol car:

→ Petrol has a CV = 34.3 MJ/litre.

→ Refinement and transportation losses (about 33% in India)

→ So, a regular petrol car giving 15 km/L has an

efficiency : $\eta = \dfrac{1}{\frac{34.3}{1-.33}} \times 15$

$$\eta = \frac{1-0.33}{34.3} \times 15 = 0.29 \text{ km/MJ}$$

→ In other ~~of~~ words, to travel a distance of 1km, a small petrol car must expend 3.45 MJ or 955 Wh of energy.

Small Electric Car :

→ An electric car in Indian road conditions consumes 90 Wh/km

$$1\ \text{Wh} = 3600\ \text{J}$$

$$90\ \text{Wh} = 324{,}000\ \text{J}$$

→ Power Plant efficiency, conversion & transmission losses in electricity in India are 70% or more.

→ So, an Indian electric car at 90 ~~kwh~~ Wh/km has an efficiency :

$$\eta = 0.93 \qquad \frac{1-0.73}{3600} \times 10^6 \times \frac{1}{90} = 0.93\ \text{km/MJ}$$

The full cycle charge & discharge efficiency of the electric car is 80%.

∴ Final efficiency : $\eta = 0.93 \times 80\% = 0.74\ \text{km/MJ}$

or

$0.74\ \text{km}/277\ \text{Wh}$

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

★★

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

★★

2) Diesel - SUV vs Electric SUV

Diesel SUV:

→ Diesel has a CV = 38.4 MJ/Litre

→ Refinement & transportation losses (abt 33% in India)

→ Regular diesel SUV giving 10 km/Litre has an efficiency of : $\eta = \frac{1-0.33}{38.4} \times 10 \text{ km/l} = 0.17 \text{ km/MJ}$ or $0.17 \text{ km}/277 \text{ Wh}$

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

Electric SUV: (Tesla model X)

→ Has an efficiency of 237.5 Wh/km

$1 \text{ Wh} = 3600 \text{ J}$

$237.5 \text{ Wh} = 855{,}000 \text{ J}$

→ Power plant efficiency, conversion & transmission loses are 70% or more.

→ So, a Tesla model at 237.5 Wh/km has an efficiency of 0.35 km/MJ.

→ Full cycle charge & discharge efficiency is 90%.

∴ Final efficiency : $0.35 \times 90\% = 0.32 \text{ km/MJ}$ or $0.32 \text{ km}/277 \text{ Wh}$

→ In other words, to travel a dist of 1 km, an elec SUV will expend 3.12 MJ or 867 Wh of energy.

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

3) Petrol scooter vs Electric scooter

Petrol Scooter:

→ Petrol has a CV = 34.3 MJ/Litre

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

→ So, a regular petrol scooter giving 50 km/L has an efficiency of 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.

Electric Scooter: (Ather S340)

→ An electric scooter consumes 33 Wh/km.

→ Power plant efficiency, conversion and transmission losses are 70% or more.

→ So, indian elec. scooter at 33 Wh/km has an efficiency of 2.52 km/MJ

→ Full cycle charge and discharge efficiency of bike is 90%

→ ∴ Final efficiency = 2.52 × 90% = 2.26 km/MJ
or
2.26 km/277 Wh

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

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

30/03/24

Traction motor

→ Electric vehicles act with electric motors using DC.

→ Types of electric motors include-

→ Brushless DC motor (BLDC) MCQ ans

→ AC induction motor (ACIM)

→ Permanent magnet synchronous motor (PMS)

→ Permanent magnet switched reluctance motor (PMSRM)

* → The inverter converts AC or DC electrical energy into AC energy suitable for the operation of electric motor.

* → The inverter adjusts the frequency and amplitude of the AC with the help of a microcontroller and the microcontroller controls the change in rotating speed, power and torque of electric motor.

Selection of Traction motor used in Electric Vehicles:

→ High torque at the time of 1st movement.

→ Low power consumption and efficiency at high speeds that is Good performance

→ matching of desired characteristics

→ suitable mechanical & electrical features

→ Effective speed control

→ ~~Attick~~

* Mechanical Characteristics of Traction Motor (6M Q)

→ Robustness
- must be strong enough to withstand continuous vibration & other forces acting during running of train

→ Lightweight
- Higher power to weight ratio
- lesser the weight of motor, higher the operating efficiency

→ Totally enclosed
- Protects itself ~~from~~ against ingress of dust, dirt, 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

→ ~~Hig~~

* Electrical Characteristics of Traction Motor

→ High starting torque

- Capable of developing high starting torque as train has to start with heavy load and accelerate to max. speed.

→ Parallel Running

- Can be operated in parallel and mechanically coupled so as to share the load almost constant.

→ Simple and Easy speed Control

- To start and stop frequently, easy & simple and economical speed control is preferred.

→ Voltage fluctuation.

-

→ Easy Electric Braking

- Easy and simple

→ High efficiency

- High mechanical & electrical efficiency so as to improve its efficiency.

motors usually used in EV ⟶ BLDC motors

Classification of Hybrid EV

Qn

[A]. Based on architecture:

1) Series configuration
2) Parallel configuration
3) Series-Parallel Hybrid Configuration

[B]. Based on degree of Hybridization:

1) micro Hybrid
2) mild Hybrid
3) Full Hybrid
4) Plug-in Hybrid

★ Micro Hybrid EV:

→ The electric motor functions to start / stop the system
→ This motor doesn't provide any additional torque.
→ Electric motor supplies power 2.5 kW at 12 Volts.
→ Energy saving 5 to 10%. (1M Qn) Example: BMW 1 series

Mild Hybrid EV:

→ Electric motor generator is integrated to provide 10% of max. engine power.

→ Electric motor supplies power 10 to 20kW at 100-200 Volts.

→ Energy saving is 20 to 30%. Example: Chevrolet Malibu, Chevrolet Silverado is a full size pickup truck, Honda Escape, etc.

* Full Hybrid EV:

→ Electric motor provides at least 40% of engine power as additional torque.

→ Electric motor supplies power 50kW at 200-300 Volts.

→ Energy saving is 30-50%.

→ Example: Toyota Pris, Ford Fusion Hybrid / Lincoln MKZ hybrid, Kia Optima Hybrid.

* Plug-in Hybrid EV:

→ Combine a gasoline or diesel engine with an electric motor and a large rechargeable battery.

→ These hybrid vehicles can be plugged in and recharged from an outlet allowing the vehicle to drive extended distances with just electricity.

→ When battery is emptied, the conventional engine turns on & vehicle operates as a conventional, non-plug-in hybrid (i.e- it uses petrol, diesel or gasoline to run the vehicle.)

→ Example: Chevrolet volt, Mitsubishi Outlander P-HEV, Toyota Prius P-HEV, etc.

C Based on Nature of Power source:

1) <u>Electric-IC engine hybrid</u>:

→ Different types of architecture is used for the power consumption. Ex: series, parallel, series-parallel.

2) <u>Fuel cells</u>:

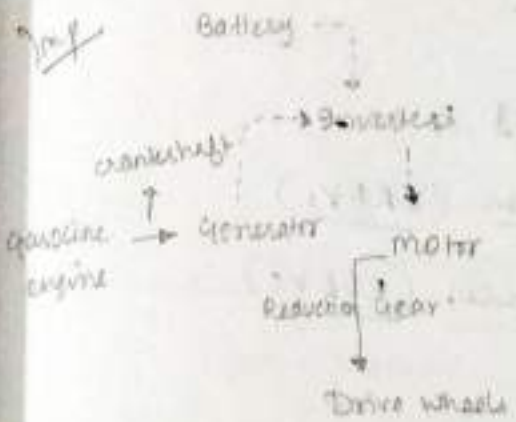
→ Main source is hydrogen.

→ They need ultra-capacitor to ↑ power density req. to start the vehicle.

→ Use of H_2 results in low use of crude oil and low carbon emission as well.

*Series EV (Based on Architecture)

Imp



→ series hybrid is to couple the ICE with the generator to produce electricity for pure electric propulsion.

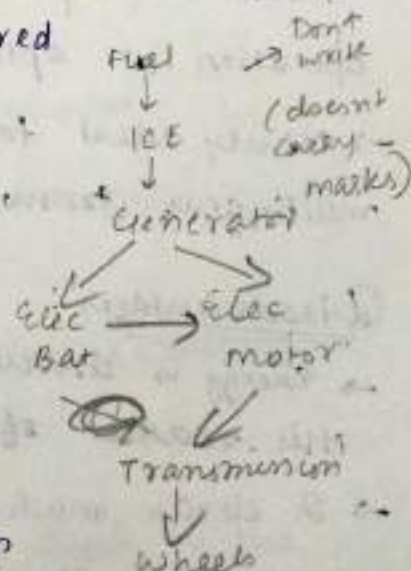
→ mechanical o/p is 1st converted into electricity using generator

→ converted electricity either charges the battery or can bypass the battery to propel the wheels ~~and~~ via the motor and mechanical transmission.

→ Conceptually, it is an <u>ICE assisted Electric Vehicle (EV)</u>.

→ In this type of HV, wheels are powered by electric motor.

→ The ICE installed in vehicle doesn't supply power to the wheels directly & hence these vehicles need large cap. batteries.



* → The series HEV is <u>more efficient</u> in <u>low speed driving</u> involving <u>frequent start - stop</u>.

→ The generator both charges a battery and powers an electric motor that moves the vehicle.

→ When large amounts of power are req., motor draws elec. from both battery & generator

→ Series HEV may also be referred to as -
- Extended Range Electric Vehicles (EREVs)
- Range Extended Electric Vehicles (REEVs)

Qn

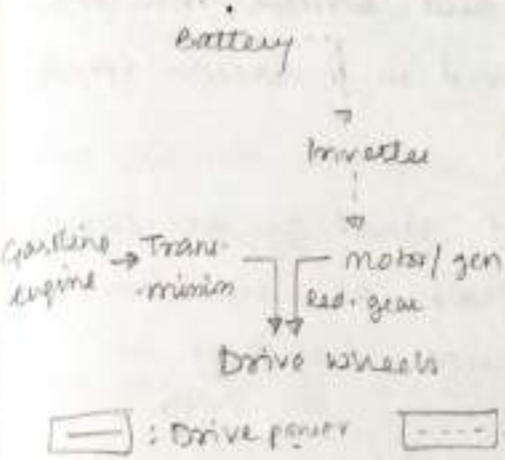
Advantages:
→ No transmission
→ No clutch
→ No torque converter
→ Mech. decoupling b/w ICE & wheels allows ICE operation at optimal.
→ Nearly ideal torque speed char. of Elec motor make multi-gear transmission unnecessary.

Disadvantages:
→ Energy is converted twice (mech → elec → mech) and this reduces efficiency.
→ 2 electric machines are ~~required~~ needed and a big motor is req because it's the only torque source of the driven wheels
→ Completely dependant on ~~[illegible]~~ battery power

Application: heavy commercial vehicles, military vehicles and buses.

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

Parallel Hybrid Vehicle



→ Allows both ICE & EM to deliver power to drive the wheels.

★→ Since both the ICE & EM are coupled to the drive shaft of the wheel via 2 clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM.

→ In this type of HEV, wheels get power from both ICE and an EM.

*→ The ICE serves as the main source of power in Parallel HEV.

→ Electric battery only supports the engine. (smaller cap battery)

*→ A parallel HEV is more effective in high-speed driving

→ The EM turns on only when a boost is needed.

Advantages:

→ Both engines & EM directly supply torque to the driven wheels and no energy form conversions occur

→ Compactness due to no both energy sources work in tandem leading to significantly less weight.

Disadvantages

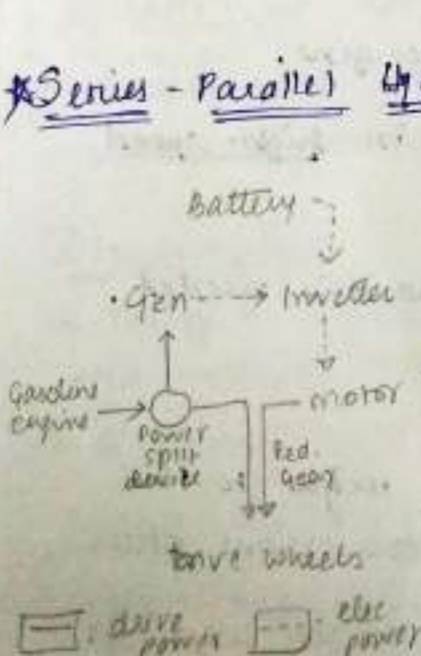
→ mechanical coupling b/w engine and wheels, thus the engine operating points can't be fixed in a narrow speed region

→ mech configuration & the control strategy are complex compared to series hybrid drive train as seamless blending of energy from dual sources resulting in complex software and hardware

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

Most passenger cars employ this configuration.

*Series - Parallel Hybrid Vehicle



→ In this series-parallel hybrid, the config incorporates the features of both series & parallel HEVs.

*→ ICE is used to charge the battery as well as drive the wheels resulting in higher efficiency & performance.

→ However, this config needs an additional elec machine and a planetary gear unit to control the complex configuration.

nowadays not required.

→ This type of ~~hyb~~ HEV depending upon the load on the vehicle, it can act like series-hybrid or parallel-hybrid vehicle.

→ The control module governs the selection of the most suitable mode.

Components of a HYBrid vehicle

1) Electric motor / Traction motor:

→ It transforms elec. energy stored in battery into mech energy.

2) Electric battery

→ Stores the elec energy

3) Inverter

→ performs fn of converting the DC from the battery to AC for the motor.

4) DC converter

→ converts higher voltage DC from battery pack to lower voltage DC, with the help of inverter & microcontroller. ~~from~~

5) Electric generator

→ produces electricity when driven by an external power source like ICE.

→ Series hybrid uses this component where an ICE drives generator to produce elec. which then charges the battery.

6) Control Module.

→ controls the entire operation of a vehicle by synchronizing all the power sources employed.

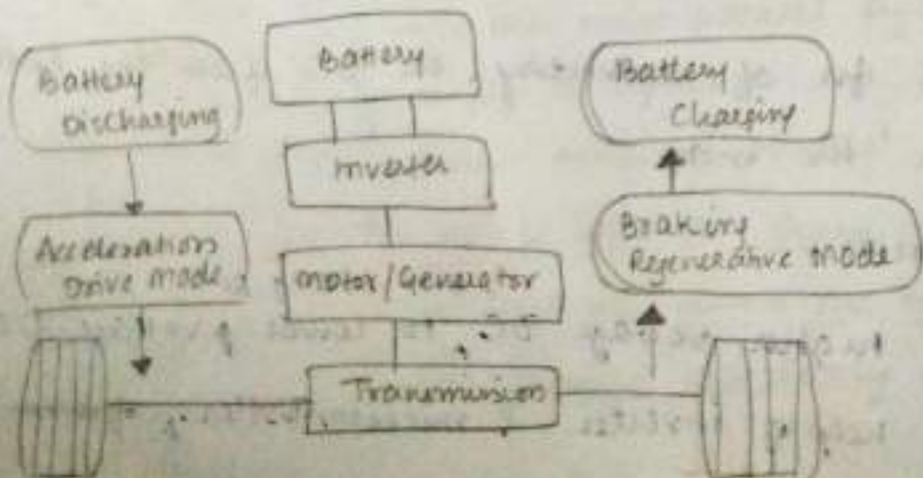
Regenerative Breaking Principle

→ Regenerative Braking is the recovery of K.E. during braking.

→ HEV/EV can use the EM to recover a portion of K.E.

→ Regenerative braking enables

- extended range in EV
- lower fuel consumption
- ~~improves~~ controls CO_2 emissions in Hybrid vehicles.



→ As driver operates brake pedal, the EM switches to a generator motor.

→ wheels transfer the KE through the drive train to the generator.

→ Through the rotary motion, generator converts a portion of KE to elec. energy.

→ motor controller/ Microcontroller enables the switching to generator mode.

* → The breaking torque is continuosly adapted by the friction breaking to the current generative braking torque. This process is called Torque Blending.

Advantages of a Hybrid Vehicle:

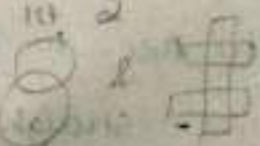
→ Environmentally Friendly
→ Economical
→ less fossil fuel Dependant
→ Regenerative Braking system
→ light Build
→ Higher resale value

Examples:
Toyota Prius
Honda Insight

Disadvantages of a Hybrid Vehicle:

→ less power
→ Expensive to purchase
→ poorer handling
→ High maintenance cost
→ High voltage Batteries

A in A-4 sheet classify gears with neat diag. explain Spur gears, only 1st 2



Helical gears, Bevel gears

closing & opening to door metro ← worm gear, rack & pinion elliptical gears