

MODULE 3

HEAT ENGINES

A Heat engine is a thermal prime mover that converts the chemical energy of a fuel into heat energy by combustion of fuel and utilizes this energy to perform mechanical work. Heat engines are broadly classified into two categories

1) External Combustion Engines (E.C. Engines): In these engines, combustion of fuel takes place outside the engine cylinder. Ex: Steam engines, Steam turbines, closed cycle gas engine, etc. The EC engines are mainly used for large electric power generators.

2) Internal Combustion Engines (I.C. Engines): In IC Engines, the combustion of fuel takes place inside the engine cylinder. Ex: Petrol Engines, Diesel Engines, Gas Engines, etc. IC Engines are mainly used for transport vehicles.

Classification of I C Engines

i) According to the type of fuel used

1. Petrol Engines
2. Diesel Engines
3. Gas engines

ii) According to the number of strokes per cycle

1. Four stroke engine
2. Two stroke engine

iii) According to the method of ignition

1. Spark Ignition engine
2. Compression Ignition engine

iv) According to the cycle of working

1. Otto Cycle engine (Constant Volume cycle engine)
2. Diesel Cycle engine (Constant Pressure cycle engine)
3. Dual Combustion cycle engine

v) According to the number of cylinders

1. Single cylinder engine
2. Multi cylinder engine

vi) According to the method of cooling

1. Air cooled engine
2. Water cooled engine

➤ **TECHNICAL TERMS RELATED TO I C ENGINES:**

1. **Bore:** It is the inside diameter of engine cylinder
2. **Top Dead Center (TDC):** The extreme position of the piston nearer to the cylinder head is known as TDC.
3. **Bottom Dead Center (BDC):** The extreme position of the piston nearer to the Crank Shaft is known as TDC.
4. **Stroke:** It is the linear distance traveled by the piston from TDC to BDC or from BDC to TDC.
5. **Swept Volume (Vs):** It is the Volume swept by the piston as it moves between TDC and BDC.
6. **Clearance Volume(Vc):** It is volume of the cylinder above the top of the piston when piston is at TDC.
7. **Compression Ratio:** It is ratio of the total cylinder volume to the clearance volume
$$\text{Compression Ratio} = \frac{V_s + V_c}{V_c}$$
8. **Piston Speed:** The average linear speed of the piston is called piston speed and is given by $S = 2 LN$ where L- stroke in m and N –speed of the engine in rpm.

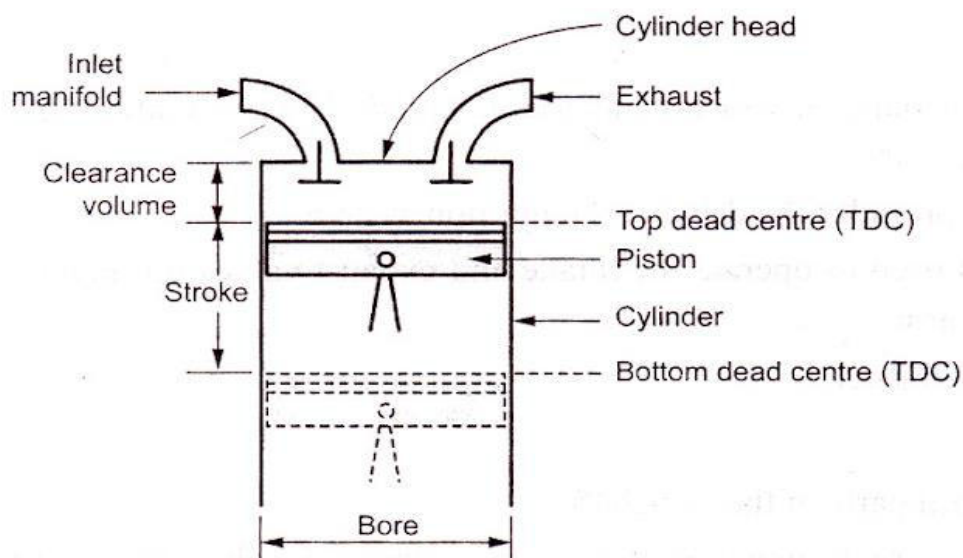


Fig 2.1: Terminologies of IC engines

➤ PRINCIPAL PARTS OF AN IC ENGINE:

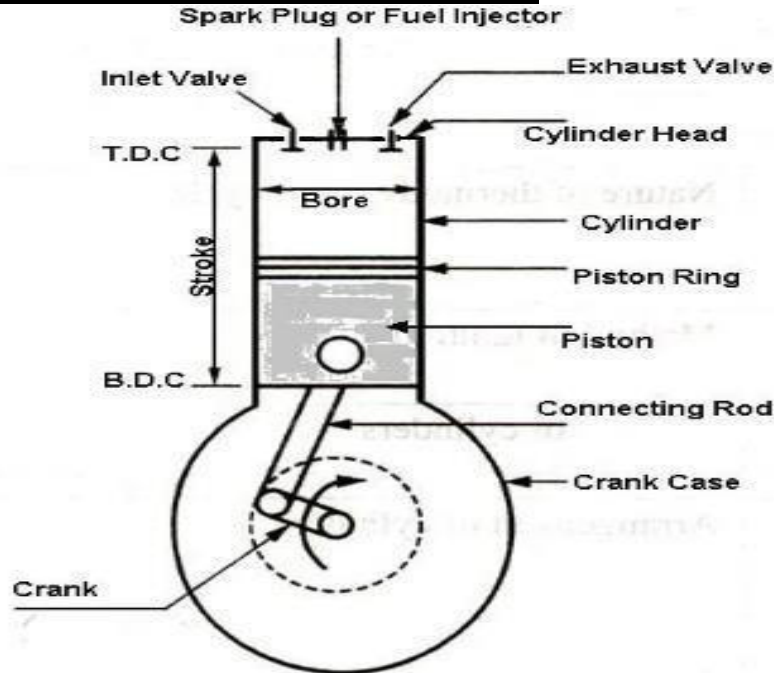


Fig 2.2: Parts of a IC engine

1) **Cylinder:** The heart of the engine is the cylinder in which the fuel is burnt and the power is generated. Its function is to contain the working fluid under pressure and to guide the piston while reciprocating inside the cylinder.

The cylinder is usually made of Grey Cast Iron or steel alloys in order to withstand the high pressure and temperature during combustion.

2) **Cylinder Head:** The top end of the cylinder is closed by a removable cylinder head. The cylinder head consists of two valves i.e. inlet and outlet valves. It is usually made of Cast iron or alloys of cast iron

3) **Piston:** It is a close fitting hollow cylindrical plunger moving to and fro in the cylinder. The main function of the piston is to compress the charge during compression stroke and to receive the impulse produced by the combustion of the fuel and to transmit the energy to the crankshaft.

4) **Piston rings:** These are the metallic rings inserted into the circumferential grooves provided at the top end of the piston. These rings maintain a gas tight joint between the piston and cylinder while the piston is reciprocating in the cylinder.

They are two sets of piston rings. One set is called compression rings which press hard against the cylinder walls forming a tight seal between piston and the cylinder. This prevents the high pressure gases from escaping into the crankcase. Another set of rings called oil rings which are used to extract the lubricating oil from the cylinder walls and to send it back to the oil sump through holes provided in the piston.

- 5) **Connecting rod:** It forms a link between piston and the crankshaft. It converts the linear motion of the piston into rotary motion of the crankshaft.
- 6) **Crank and crankshaft:** The crank is a lever that is connected to the end of the connecting rod by a pin joint with its other end connected rigidly to a shaft called crankshaft. It rotates about the axis of the crankshaft and causes the connecting rod to oscillate. The power required for any useful purpose is taken from the crankshaft.
- 7) **Fly wheel:** It is heavy wheel mounted on the crankshaft of the engine to maintain uniform rotation of the crankshaft. It is used as an energy saving device. It stores energy received during power stroke and supplies the same during other strokes.
- 8) **Crank case:** It is lower part of the engine serving as an enclosure for the crankshaft and also as a sump for the lubricating oil
- 9) **Valves:** These are the control devices that allow the air/fuel to enter into the cylinder and also discharge the burnt gases to the atmosphere. The inlet and outlet valves serve these purposes. The valves are actuated by means of springs, cam and lever mechanisms and are made to open and closed so that the charge enters/discharges at the right time

FOUR STROKE ENGINE:

A four stroke engine consists of a piston cylinder arrangement with two valves. One valve called the 'Inlet valve', through which fresh charge enters into the cylinder and the other. 'Exhaust valve', through which burnt gases are discharged out of the cylinder.

In 4-stroke engines, all the operations of the working cycle are completed in four different strokes of the piston. The four different strokes performed are:

- Suction stroke
- Compression stroke
- Expansion stroke
- Exhaust stroke

Each stroke is completed when the crankshaft rotates by 180° . Hence in a 4-stroke engine, the four different strokes (working cycle) are completed through 720° of the crankshaft rotation or two revolutions of the crankshaft.

➤ **WORKING PRINCIPLE OF FOUR STROKE PETROL ENGINE**
(CONSTANT VOLUME CYCLE ENGINE)

Fig 2.3: Four stroke petrol engine

It is also known as Otto cycle or constant volume cycle engine. It requires four strokes of the piston to complete one cycle of operations in the engine cylinder. The four strokes are as follows:

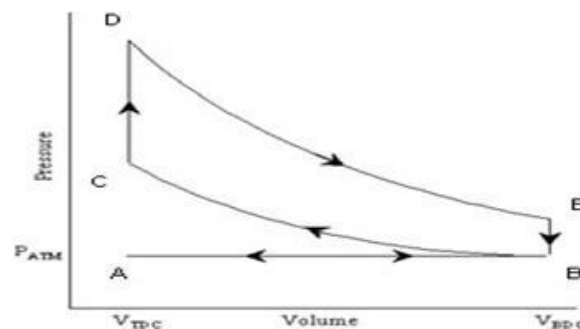


Fig 2.3 a: P-V Diagram

1. Suction stroke: During the stroke, the piston moves from TDC to BDC. The inlet valve opens and exhaust valve will be closed. The downward movement of the piston creates a suction in the cylinder and as a result, fresh charge of air-petrol mixture is drawn into the cylinder through inlet valve. When the piston reaches the BDC, the suction stroke ends and inlet valve closes. The suction stroke is represented by the line AB in P-V diagram as shown in fig 2.3 a.

2. Compression Stroke: During this stroke, the piston moves from BDC to TDC and both the valves are closed. As the piston moves upwards, the air-petrol mixture in the cylinder is compressed adiabatically. The pressure and temperature of the charge are increased and this is shown by the curve BC on PV diagram. When the piston reaches the TDC, the spark plug initiates a spark that ignites the air-petrol mixture. Combustion of fuel takes place at constant volume and this is shown in a line CD on PV diagram.

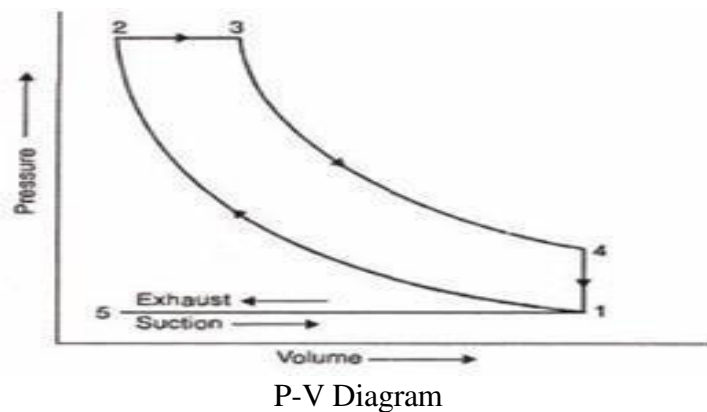
3. Power Stroke (Working stroke or Expansion stroke): During this stroke, both the valves are closed and because of the combustion of charge, the burnt gases expand. Due to this expansion, the hot gases exert pressure on the piston and as a result, the piston is pushed from TDC to BDC. The power impulse is transmitted down through the piston to the crankshaft. This causes the crankshaft to rotate at high speeds. Thus, work is obtained in this stroke. At the end of this stroke, the exhaust valve opens which will release the burnt gases to the atmosphere.

The expansion of gases is adiabatic in nature and this adiabatic expansion is shown by the curve DE on PV diagram. When the piston reaches the BDC, the exhaust valve opens. A part of the burnt gases escapes through the exhaust valve due to their expansion. The drop in pressure at constant volume is shown by the line EB on PV diagram.

4. Exhaust Stroke: During this stroke, the piston moves from BDC to TDC. The inlet valve is closed and exhaust valve is opened. As the piston moves upward, it forces the remaining burnt gases to the atmosphere through the exhaust valve. This is shown by the line BA on PV diagram. When the piston reaches TDC, the exhaust valve closes. Thus one cycle is completed.

➤ **WORKING PRINCIPLE OF FOUR STROKES DIESEL ENGINE**
(CONSTANT PRESSURE CYCLE):

Fig: Four stroke Diesel engine



Air alone is compressed during the compression stroke and at end of this stroke, the fuel injector injects fuel into the hot compressed air. The fuel is then ignited as it comes in contact with the hot compressed air. Hence these engines are called compression ignition engines. The working principle of 4 stroke diesel engine is based on Diesel cycle, hence they are called diesel cycle or constant pressure cycle engines.

The four different strokes of the 4 stroke diesel cycle is as under:

i) **Suction Stroke:** During this stroke, the piston moves from TDC to BDC. The inlet valve opens and exhaust valve will be closed. The downward movement of the piston creates a suction in the cylinder and as a result atmospheric air from the air filter is drawn into the engine cylinder through the inlet valve. When the piston reaches BDC, the suction stroke ends with closure of the inlet valve.

ii) **Compression Stroke:** During this stroke, the piston moves from BDC to TDC and both the inlet and exhaust valves are closed. As the piston moves upwards, the air inside the engine cylinder is compressed to high pressure and temperature. The compression process is adiabatic in nature and the compression ratio will be from 15:1 to 22:1. At the end of this stroke, the fuel is injected into the engine cylinder in the form of fine sprays by a fuel injector. Combustion of fuel takes place at constant pressure.

iii) **Power Stroke:** During this stroke, both inlet and exhaust valves remain closed. Due to the combustion of fuel, the burnt gases expand and exert a large force on the piston.

Due to this, the piston is pushed from TDC to BDC. The power impulse is transmitted down through the piston to the crankshaft through the connecting rod. This causes the crankshaft to rotate at high speeds. Thus power is obtained during this stroke. The expansion gases are adiabatic in nature and when the piston reaches BDC the exhaust valve opens. A part of the burnt gases escapes through the exhaust valve due to their expansion. The drop in pressure is at constant volume.

iv) **Exhaust Stroke:** During this stroke, the piston moves from BDC to TDC and the inlet valve will be closed and exhaust valve will be opened. As the piston moves upwards, it forces the burnt gases out of the engine cylinder. When the piston reaches TDC, the exhaust valve close and the next cycle of suction stroke begins. Thus in this engine, four operations are completed in two revolutions of the crank shaft or 4strokes of the piston and the power is obtained during only in power stroke i.e. one power stroke for two revolutions of the crankshaft.

➤ COMPARISON OF PETROL ENGINE AND DIESEL ENGINE:

S.No	Petrol Engine	Diesel Engine
1	Follows Petrol Cycle	Follows Diesel Cycle
2	Petrol is used as Fuel	Diesel is used as Fuel
3	Ignition is by Spark ignition	Ignition is by Compression ignition
4	Fuel is supplied to the cylinder by Carburetor	Fuel is supplied to the cylinder by Fuel injector
5	Running cost is more	Running cost is less
6	Low compression ratio(6:1 to 8:1)	High compression ratio(15:1 to 22:1)
7	Noise level is less	Noise level is more
8	Can easily be started in cold condition	Difficult to start in cold condition
9	Initial cost is less	Initial cost is more
10	Engine weight is less	Engine weight is more

➤ PARAMETERS INVOLVED IN IC ENGINES:

The job of an internal combustion engine is to convert heat energy into mechanical energy. Practically it means that an IC engine of any type produce mechanical work in the form of a rotating shaft giving some torque at some value of r.p.m by continuously burning of fuel. Performances of IC engine means that how will it complete the above mentioned job. It can be measured or compared only in terms of certain parameters as mentioned in this chapter. These parameters are called performance parameters.

➤ Indicated Power (IP)

The total power developed by combustion of fuel in the combustion chamber is called Indicated Power (IP). It can be calculated as:

$$I.P = \frac{n P_{mi} L A N K \times 10}{6} \text{ kW}$$

Where n = number of cylinders

P_{mi} = Indicated mean effective pressure, (bars)

L = Length of stroke, (m)

A = Area of piston, (m²)

K = 1/2 for 4 stroke engine

= 1 for 2 stroke engine

➤ Brake Power (BP)

The power available at an engine's output shaft is called its brake power. It is the power which can be positively used against resistive force or braking force of the application for which engine is being used. It can be calculated as

$$B.P = \frac{2\pi NT}{60 \times 1000} \text{ kW}$$

Where N = engine speed in rpm

T = Torque at output shaft in N-m.

➤ Friction power (FP)

The total power loss by the moving parts in the cylinder. In other words, it is the difference between Indicated power and Brake power.

$$FP = IP - BP \text{ in kW}$$

➤ **Mechanical efficiency**

It is the ratio of brake power to the indicated power of an IC Engine.

$$\eta_{mean} = \frac{B.P}{I.P}$$

APPLICATIONS OF IC ENGINES:

Following are the application of IC engine:

1. IC engines are used in Road vehicles like scooters, motorcycles, buses etc.
2. It is also used in Aircraft.
3. IC engine is commonly used in Motorboats.
4. IC engine has great application in small machines, such as lawnmowers, chainsaws, and portable engine-generators.

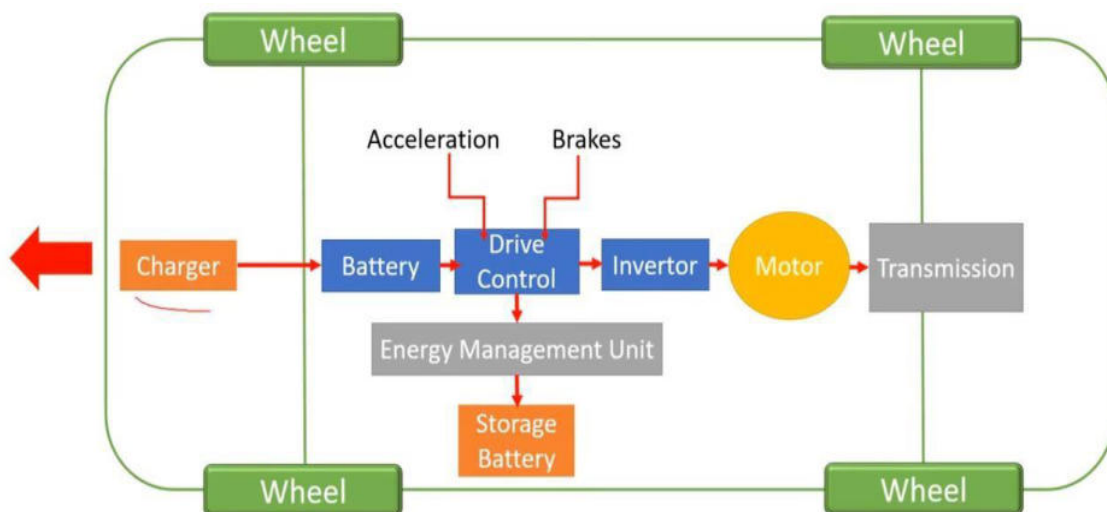
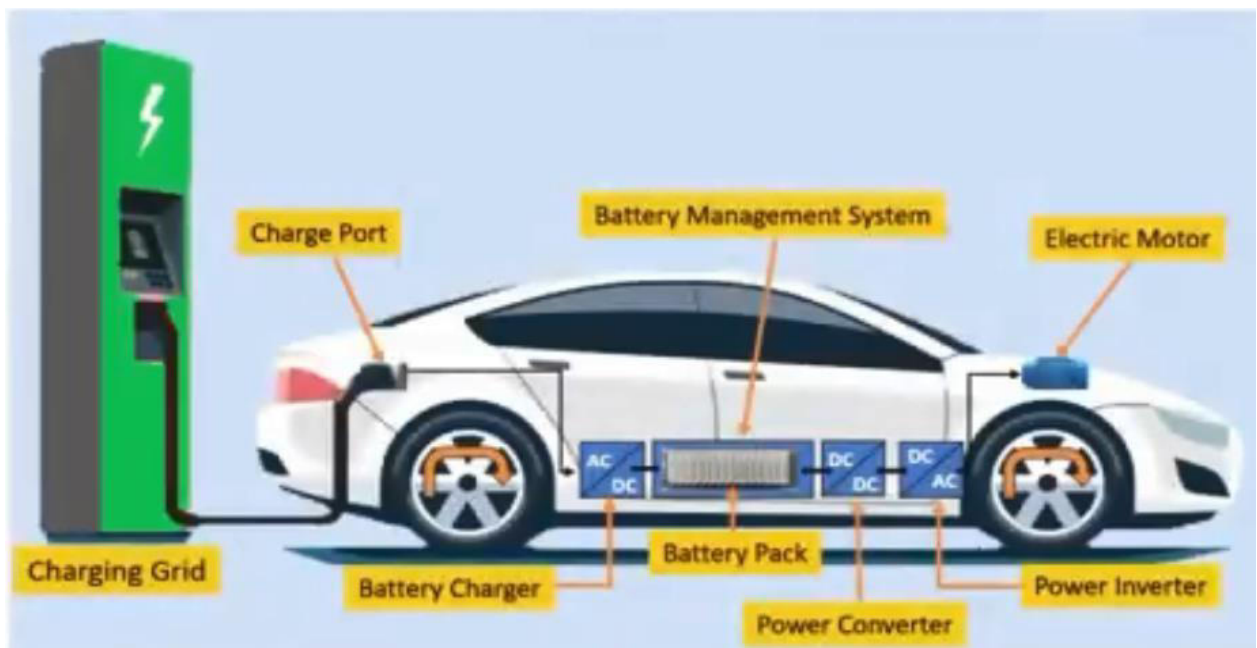
ELECTRIC VEHICLES

Introduction

An electric vehicle, also called an electric drive vehicle, uses one or more electric motors or traction motors for propulsion. An electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels or a generator to convert fuel to electricity.

EVs include road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

Components of Electric Vehicles:



1. **Charge port:** Connects to external power grid and charges the battery pack. It is present in Battery and plug in hybrid cars.

2. Battery charger:

- Converts AC received through Charge port to DC. To store in battery pack.

3. **Battery pack:** it is the main source in case of electric vehicle. It stores electrical energy in the form of DC current. It is the set of any number of individual battery cells. It is configured in series, Parallel and combination. Li-ion battery is commonly used.

3. Battery management System:

- It is an electronic system that manages the battery pack.
- By protecting the battery from operating outside its safe area.
- Its functions like- Monitoring its state
 - Reporting that data
 - Controlling its environment
 - Cell-balancing.

4. Power converter-

- It is a DC/DC converter.
- It takes the voltage from DC source and converts DC voltage level into another DC voltage level. Used to increase or decrease voltage level.

5. Power Inverter:

- it converts DC on the battery into AC.
- It is used by electric motor to drive the wheels.
- During regenerative braking, AC is converted to DC and then used to recharge the battery.

6. **Electric motor:** It converts electric energy to Mechanical energy to drive the vehicles.

ADVANTAGES OF ELECTRIC VEHICLES

1. **Environment-friendly:** Electric vehicles do not use fuels for combustion and hence there is no emission or exhaust of gasses. Vehicles using fossil fuels are large contributors to harmful gas build-up in the environment so the use of an electric car can help contribute to a cleaner atmosphere.
2. **Renewable energy source:** Electric vehicles run on electricity that is renewable whereas conventional cars work on the burning of fossil fuels that exhaust the fossil-fuel reserves on earth.

3. **Cost-effective:** Electricity is much cheaper than fuels like petrol and diesel which suffer a frequent price hike. The recharging of batteries is cost-effective if solar power is used at home.
4. **Low maintenance:** Electric vehicles have fewer moving parts so wear and tear is less as compared to conventional auto parts. Repair work is also simple and less expensive relative to combustion engines.
5. **Less noise and smoother motion:** Electric vehicles give a much smoother driving experience. The absence of rapidly moving parts makes them much quiet with low sound generation.
6. **Government support:** Governments in various countries have offered tax credits as an incentive to encourage people to use electric vehicles as a go-green initiative.

DISADVANTAGES OF ELECTRIC VEHICLES

1. **High initial cost:** Electric vehicles are still very expensive and many consumers consider them not as affordable as conventional vehicles.
2. **Charging station limitations:** People who need to drive long distances are worried about getting suitable charging stations midway which is not available everywhere.
3. **Recharging takes time:** Unlike conventional cars that require a few minutes for refilling fuel, recharging of the electric vehicle takes much more time which is generally a few hours.
4. **Limited choices:** Presently there aren't too many electric models of cars available to choose from when it comes to the looks, designs, or customized versions.
5. **Less driving range:** The driving range of the electric vehicles is found to be less as compared to conventional vehicles. Electric vehicles can be suitable for day-to-day travel but can be problematic for a long-distance journey

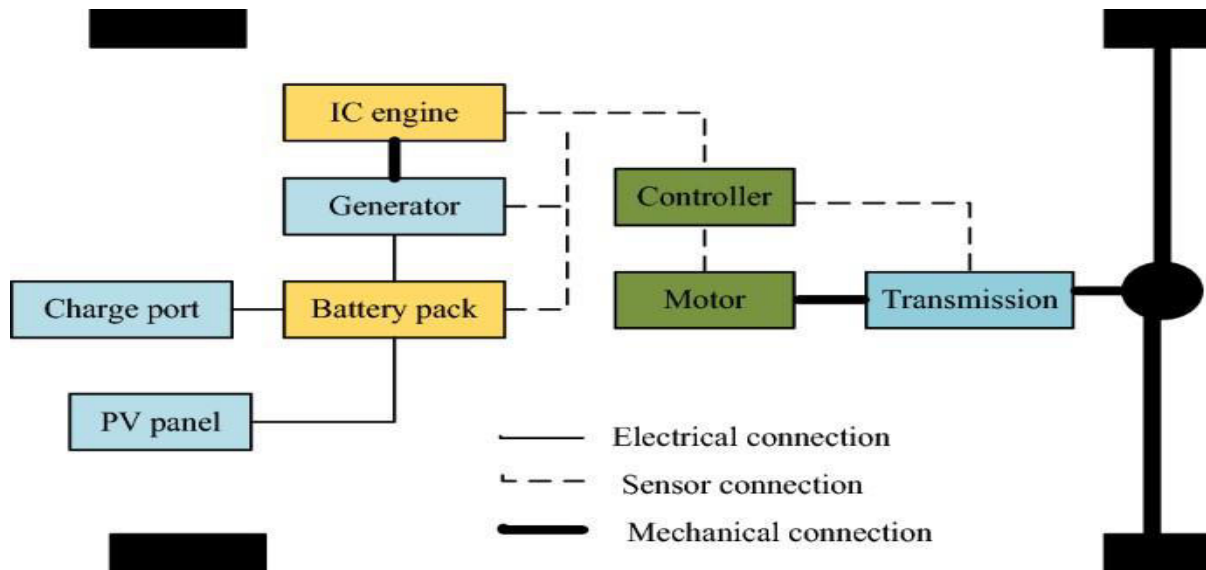
HYBRID ELECTRIC VEHICLES:

A hybrid vehicle is a vehicle that uses two or more distinct power sources to run. Ordinarily, the vehicle which we use daily derives the power from only one source i.e. an IC engine which runs on Petrol or Diesel.

But, in case of a hybrid vehicle, in addition to the IC engine, there is an electric battery which is capable of supplying power to run the vehicle. Hence, such vehicles are called 'Hybrid vehicles'. An internal combustion engine used in a hybrid vehicle may either run on Petrol or Diesel fuel.

For example, a truck that uses a diesel to drive a generator, which in turn drives several electrical motors for all-wheel drive, is not a hybrid. But if the truck has electrical energy storage to provide a second mode, which is electrical assists, then it is a **hybrid Vehicle**. These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with both mechanisms driving the car directly.

Main components of a Hybrid vehicle:



1. An internal combustion engine (i.e. Petrol engine / Diesel engine): In most of the hybrid vehicles, IC engine acts as the main source of power.
2. Electric motor: It transforms the electric energy stored in a battery into mechanical energy i.e. it drives wheels with the help of electricity stored in a battery.
3. Electric battery: Its function is to store electric energy and supply it whenever necessary.
4. Inverter: Electricity stored in an electric battery is in the form of Direct Current (DC) while the majority of the motors used in the present day hybrid vehicles require Alternating Current (AC) to run. So, an Inverter performs the function of converting the DC from the battery to AC for the motor.
5. Electric Generator (Exclusive for series & series-parallel hybrids): The function of a generator is to produce electricity when driven by an external power source. Series hybrids use this component where an IC engine drives a generator to produce electricity which then charges the battery.

6. Control Module: It is the most important component of the hybrid vehicle. It controls the entire operation of the vehicle by synchronizing all the power sources employed.

ADVANTAGES OF HYBRID ELECTRIC VEHICLES

1. Electric motor drive: since electric motor provides power to help the engine in accelerating or moving up, a smaller, more efficient IC engine may be used. In addition, at low speeds, IC engine is completely shut off, the complete power required is provided by electric motor, which is more efficient than IC engine at low speeds.
2. Automatic start / stop
3. Provides regenerative braking to capture energy during braking.
4. Lower emissions and better mileage.
5. Lesser weight due to smaller engine.

DISADVANTAGES OF HYBRID ELECTRIC VEHICLES

1. High initial cost
2. Significant cost of the battery pack which has to be replaced every few years.
3. More weight due to battery
4. Lower acceleration than the cars running with IC engines.

DIFFERENCE BETWEEN ELECTRIC CARS AND HYBRID EVs

Power Transmission systems

Power transmitted from the prime movers to machines (lathe, drilling machines etc.) by means of intermediate mechanisms called drives. There are various types of drives

1. Gear drives
2. Belt drives
3. Chain drives
4. Ropes drives

The **selection of particular type of drive** depends on the application, that is the amount of power transmitted, distance between the two shafts etc.



Figure: Transmission Flow Diagram

Gear: A wheel provided TEETH is called GEAR. Gears are toothed wheels used to transmit power or motion from one shaft to another, where the distance between the two shafts is relatively small.

Gears are generally used for one of four different reasons

- i. To reverse the direction of rotation
- ii. To increase or decrease the speed of rotation
- iii. To move rotational motion to a different axis
- iv. To keep the rotation of two axes synchronized.

Spur Gear Terminology

The terminology used in spur gear

a. Pitch Circle: It is a theoretical or an imaginary circle upon which all computations are made.

b. Pitch circle diameter (PCD): It is the diameter of the pitch circle or it is the mean diameter of the gear wheel.

c. Pitch (circular pitch): It is the distance from a point on one tooth to the corresponding point on the next tooth measured along the pitch circle.

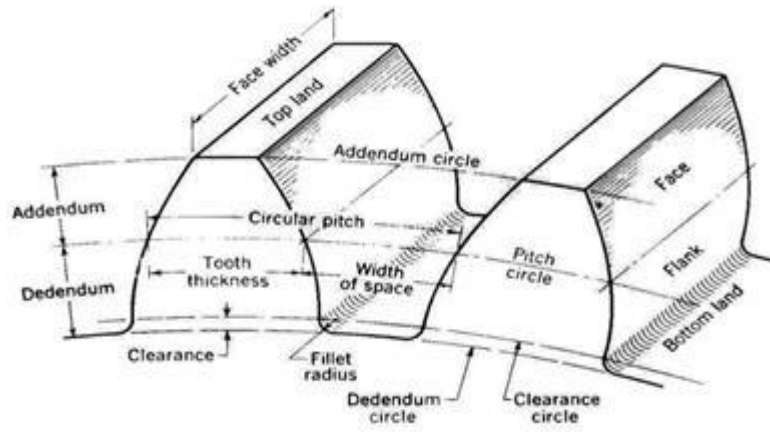
d. Module (m): It is the ratio of the pitch circle diameter of a gear in millimeter to the number of teeth.

$$m = D/T$$

where, D= pitch circle diameter in mm and

T= number of teeth.

Module refers to the index of the tooth size



e. Addendum: It is radial distance of a tooth from the pitch circle to the top of the tooth.

f. Dedendum: It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.

TYPES OF GEARS

There are various types of gears classified:

1. According to the position of axes of the shafts

a. Parallel

- i. Spur Gear
- ii. Helical Gear
- iii. Rack and Pinion

b. Intersecting - Bevel Gear

c. Non-intersecting and non-parallel - worm and worm gears

2. According to the peripheral velocity of the gears

- a. Low velocity gear- Less than 3m/s
- b. Medium velocity gears
- c. High velocity gears

3. According to the type of gearing

- a. Internal Gearing
- b. External Gearing

4. According to the position of teeth on the gear surface, it is classified as

- a. Straight Teeth-Spur gears
- b. Inclined teeth- Helical gear
- c. Curved teeth- Spiral gear

1. Spur Gears

- Parallel and co-planer shafts connected by gears are called spur gears. The arrangement is called spur gearing.
- Spur gears have straight teeth and are parallel to the axis of the wheel. Spur gears are the most common type of gears.
- The advantages of spur gears are their simplicity in design, economy of manufacture and maintenance, and absence of end thrust. They impose only radial loads on the bearings.
- Spur gears are known as slow speed gears. If noise is not a serious design problem, spur gears can be used at almost any speed.

Uses: Machine tools, gear boxes, wind-up alarm clock and watches, precision measuring instruments etc. Spur gears are not used in automobiles, because each time a gear tooth engages a tooth on the other gear, the teeth collide and this impact makes a noise. It also increases the stress on the gear teeth.

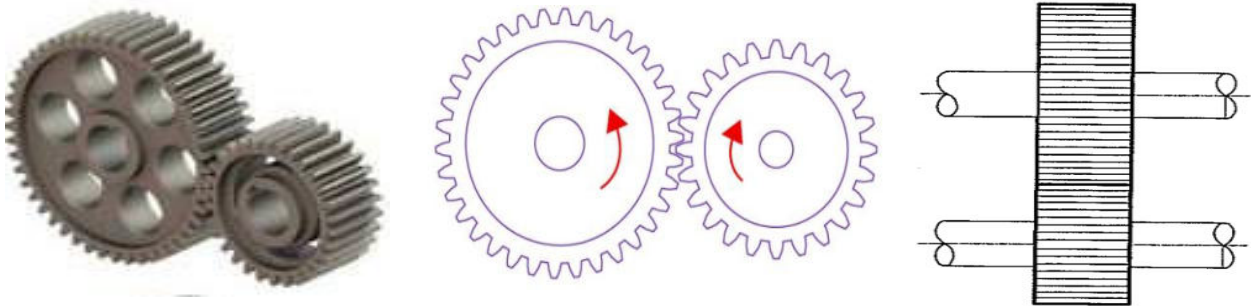


Figure: Spur gear

2. Helical Gears

- Helical gears have their teeth inclined to the axis of the shafts in the form of a helix, hence the name helical gears.
- These gears are usually thought of as high speed gears.
- Helical gears can take higher loads than similarly sized spur gears.
- The motion of helical gears is smoother and quieter than the motion of spur gears.
- Single helical gears impose both radial loads and thrust loads on their bearings and so require the use of thrust bearings.
- The angle of the helix on both the gear and the must be same in magnitude but opposite in direction, i.e., a right hand pinion meshes with a left hand gear.

Uses: Helical gears are mostly used in automobile power transmission where smooth and

quite running is necessary at higher speeds.

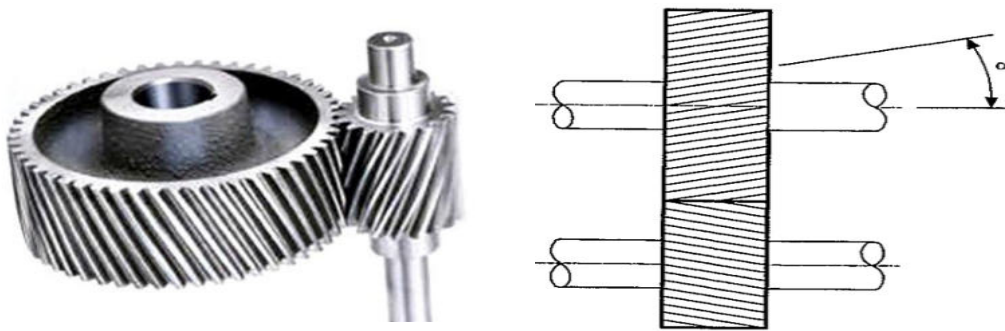


Figure: Helical Gear

3. Bevel Gears

- Bevel gears are used in transmitting power between two intersecting shafts.
- They are usually mounted on shafts that are 90° apart, but can be designed to work at any angles as well.
- The teeth are cut on the outside of the conical surface and vary in cross section throughout their length. Since the diameter of cone is greatest at its base, the teeth will be thicker at the base.
- The teeth on bevel gears can be straight, spiral or hypoid.
- Straight bevel gear teeth actually have the same problem as straight spur gears teeth- as each tooth engages, it impacts the corresponding tooth all at once.
- The solution to this problem is to curve the gear teeth and such gears are called spiral bevel gears.
- In these gears, the contact starts at one end of the gear and progressively spreads across the whole tooth.

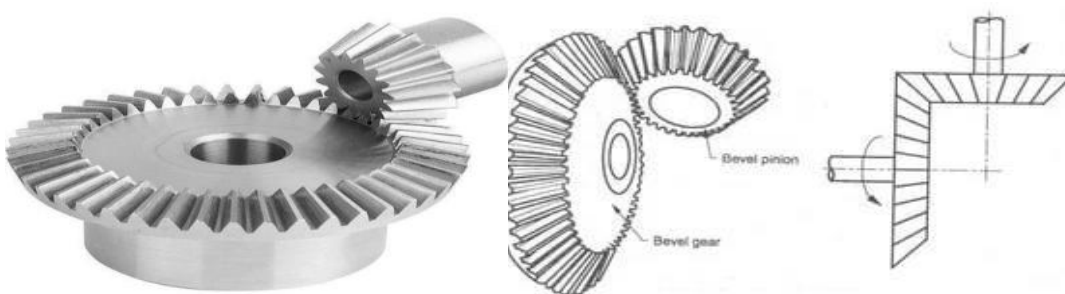


Figure: Straight Bevel Gear

4. Worm Gears

- Worm gears are used to transmit power or motion between two shafts having their axis at right angles and non-intersecting.

- Worm gear is a type of screw gearing that consists of a screw meshing with helical gear. The screw is called worm and gear wheel meshing with the wheel is called worm gear or worm wheel.
- Worm gears are widely used when large gear reductions are needed.
- It is common for worm gears to have reductions of 20:1 and even up to 300:1 or greater.

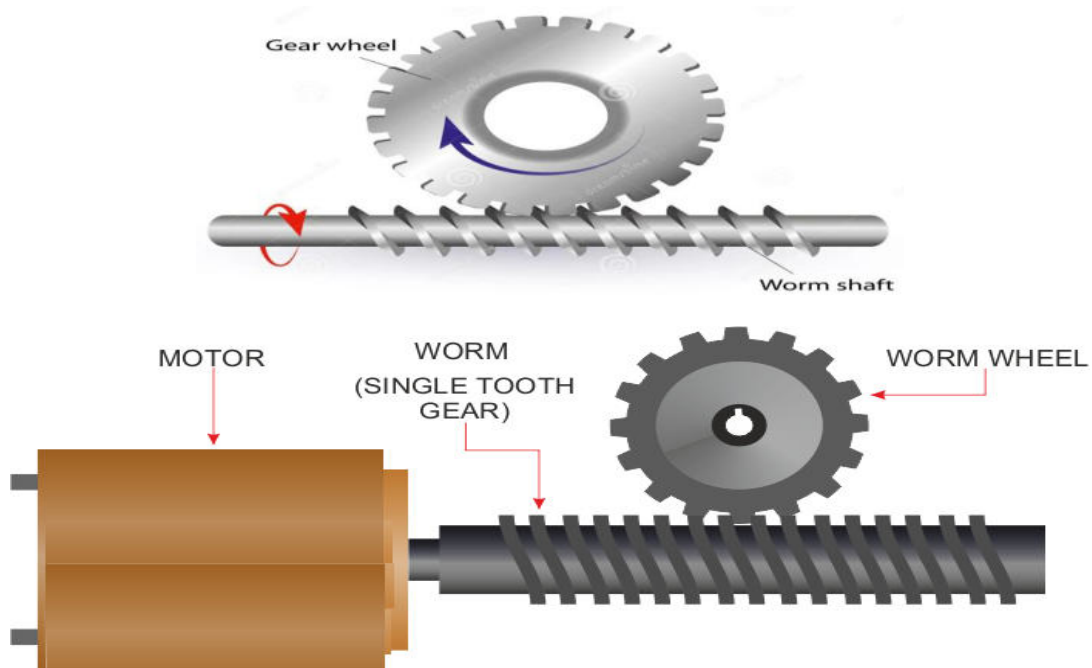


Figure: Worm gear

5. Rack and Pinion

- A rack is a gear, having teeth cut along a straight line, while a pinion is a gear with teeth cut along its periphery
- With the help of rack and pinion, rotary motion can be converted into linear motion.

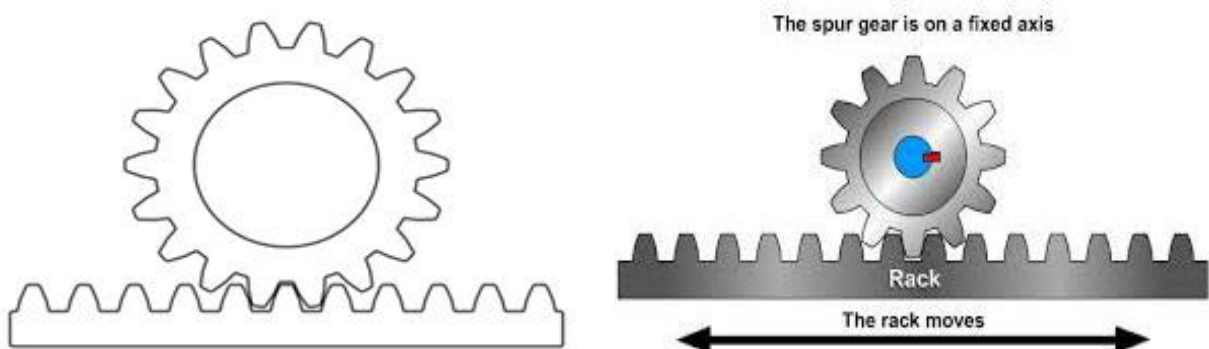


Figure: Rack and Pinion

GEAR TRAINS

As discussed earlier, gears are toothed wheels used to transmit power from one shaft to another. When two or more gears are used to transmit power, the arrangement is then called **GEAR TRAIN**. The nature of 'train' that is, the number of gears used depends upon the desired velocity ratio and the relative position of the axis of shafts.

Depending upon the arrangement of wheels, gear trains are classified as

1. Simple gear train
2. Compound gear train
3. Reversed gear train and
4. Epicyclic gear train

➤ SIMPLE GEAR TRAIN:

- A simple gear train consists of a number of gears mounted over the shaft, such that each shaft carries only one gear.
- When there is only one gear on each shaft, as shown in Figure (a), it is known as simple gear train.
- The gears are represented by their pitch circles.

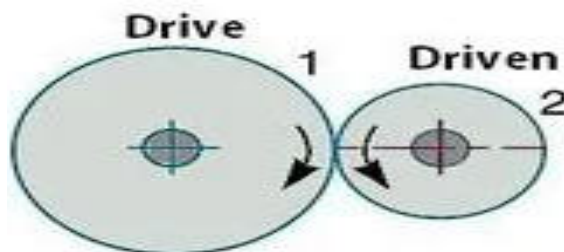


Figure 1: Gear trains

Let, N_1 = Speed of gear 1 or driver in rpm

N_2 = Speed of gear 2 or follower/driven in rpm

T_1 = Number of teeth on gear 1/driver

T_2 = Number of teeth on gear 2/ driven

There are certain cases, when power is to be transmitted between two shafts that are at large distances. This can be done by providing one or more intermediate gears as shown in the figure (b). these intermediate gears are called as '**idler gears**'.

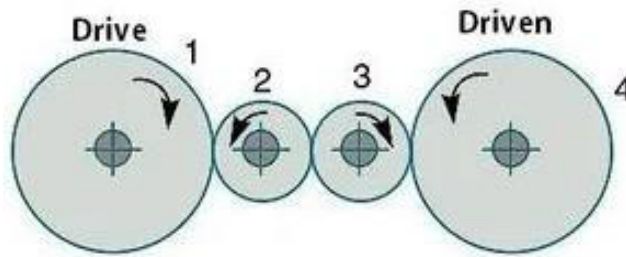


Figure 2: simple gear train with Intermediate gears.

Let N_1, N_2, N_3 and N_4 be the speeds and T_1, T_2, T_3 and T_4 be the number of teeth on gear 1, 2, 3 and 4 respectively.

Gear 1 drives gear 2

$$\text{Velocity ratio} = \frac{N_2}{N_1} = \frac{T_1}{T_2} \quad \dots\dots\dots(i)$$

Gear 2 drives gear 3

$$\text{Velocity ratio} = \frac{N_3}{N_2} = \frac{T_2}{T_3} \quad \dots\dots\dots(ii)$$

Similarly, Gear 3 drives gear 4

$$\text{Velocity ratio} = \frac{N_4}{N_3} = \frac{T_3}{T_4} \quad \dots\dots\dots(iii)$$

The velocity ratio of the gear train as shown in figure (b) is obtained by multiplying the equations (i), (ii) and (iii)

$$\text{Therefore,} \quad \text{Velocity ratio} = \frac{N_2}{N_1} \times \frac{N_3}{N_2} \times \frac{N_4}{N_3} = \frac{T_1}{T_2} \times \frac{T_2}{T_3} \times \frac{T_3}{T_4}$$

or

$$\text{Velocity ratio} = \frac{N_4}{N_1} = \frac{T_1}{T_4}$$

That is,

$$\text{Speed ratio} = \frac{\text{Speed of last gear (driven)}}{\text{Speed of first gear (driver)}} = \frac{\text{No. of teeth on first gear (driver)}}{\text{No. of teeth on last gear (driven)}}$$

Thus from the above equation, it is clear that idler gears do not affect the velocity ratio. They only serve to fill the gap and also help in achieving the required direction of rotation for the driven wheel.

➤ COMPOUND GEAR TRAIN

- A compound gear train is the one, in which each shaft carries two or more gears.
- It was clear that, from discussions made in the previous section, intermediate gear does not affect the speed ratio. Thus, whenever the distance between the two shafts is large and at the same time, higher or much less speed is required, compound gears are provided with intermediate shafts. A compound gear train is shown in figure below.

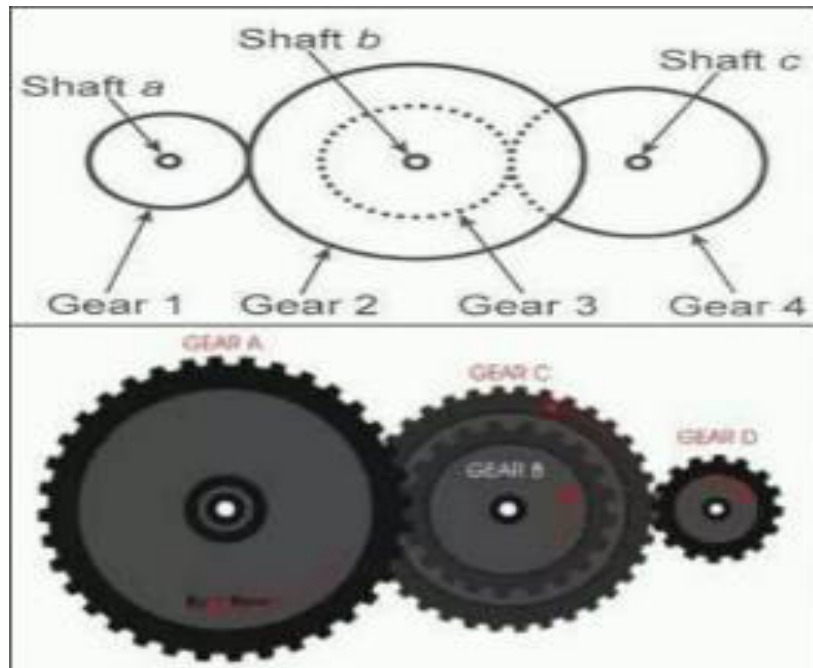


Figure: compound gear train

Let N_1, N_2, N_3 and N_4 be the speeds and T_1, T_2, T_3 and T_4 be the number of teeth on gear 1, 2, 3 and 4 respectively.

Gear 1 drives gear 2

$$\text{Velocity ratio} = \frac{N_2}{N_1} = \frac{T_1}{T_2} \quad \dots\dots\dots(i)$$

Similarly, Gear 3 drives gear 4

$$\text{Velocity ratio} = \frac{N_4}{N_3} = \frac{T_3}{T_4} \quad \dots\dots\dots(ii)$$

The velocity ratio of the gear train as shown in figure (b) is obtained by multiplying the equations (i) and (ii)

$$\text{Therefore,} \quad \frac{N_2}{N_1} \times \frac{N_4}{N_3} = \frac{T_1}{T_2} \times \frac{T_3}{T_4} \quad \dots\dots\dots(iii)$$

$N_2 = N_3$ since gear 2 and gear 3 are keyed to the same spindle.

$$\text{Velocity ratio} = \frac{N_4}{N_1} = \frac{T_1}{T_2} \times \frac{T_3}{T_4}$$

$$\text{Speed ratio} = \frac{\text{Speed of last gear (driven)}}{\text{Speed of first gear (driver)}} = \frac{\text{Product of number of teeth on driver}}{\text{Product of number of teeth on driven}}$$

Concepts of automatic and CVT transmission

The engine is the heart of the car and transmission is a heartbeat. The transmission system plays a crucial role in regulating the speed of the engine. It helps drivers to make a safe and smooth drive with controlled motion.

Transmission controls the speed by transferring power from engine to wheels. It functions when the driver changes the gears in different driving conditions.

An automatic transmission is an automobile gearbox that can change gear ratios automatically as the vehicle moves, freeing the driver from having to shift gears manually.

OPERATION OF AN AUTOMATIC TRANSMISSION:

- Most Automatic Transmission have 3 or four forward speed.
- They also have PARK, NEUTRAL, and REVERSE.
- 4th speed is usually has a overdrive ratio. Some others have fifth gear which is an overdrive.
- A typical Automatic Transmission move the vehicle in 1st gear. Then it shifts to 2nd, 3rd & 4th without assistance from driver. They happen automatically as vehicle speed increases & the engine load or throttle opening decreases.
- To slow and stop the vehicle the driver only needs to release accelerator pedal or apply brake.
- The Automatic Transmission disengages the torque converter clutch & automatically downshifts until 1st gear when the vehicle stops.
- Slippage in the torque converter allows the engine to idle with the transmission in gear.

CONTINUOUS VARIABLE TRANSMISSION (CVT)

Transmission which is an automatic gear changing technique which doesn't have a fixed gear ratio. Whereas conventional cars comprise a manual transmission requiring hard shifts between the gears. That's why CVT cars are popular as shiftless or single speed cars.

Working of CVT Transmission

- Manual and automatic transmission systems use complex gear-shifting mechanisms, which rely on the engagement of certain gears to create varied gear ratios.
- On the other hand, a Continuously Variable Transmission (CVT) has a dual-pulley mechanism that provides an infinite number of gear ratios instead of only one or two.
- These pulleys are connected by belt drive; the primary pulley is attached to the engine, while the secondary pulley is attached to the drive shaft. Because of its

moving sheaves, each pulley can extend and contract at the same time.

- The motion of their sheaves changes the diameter of both pulleys as the engine rotates. The size of one pulley grows while the other lowers, and vice versa. The constant change in pulley size results in a smooth variation in diameters, which generates an endless range of gear ratios.

