ORISSA SCHOOL OF MINING ENGINEERING

KEONJHAR

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

ON

AUTOMOBILE ENGINEERING & HYBRID VEHICLES

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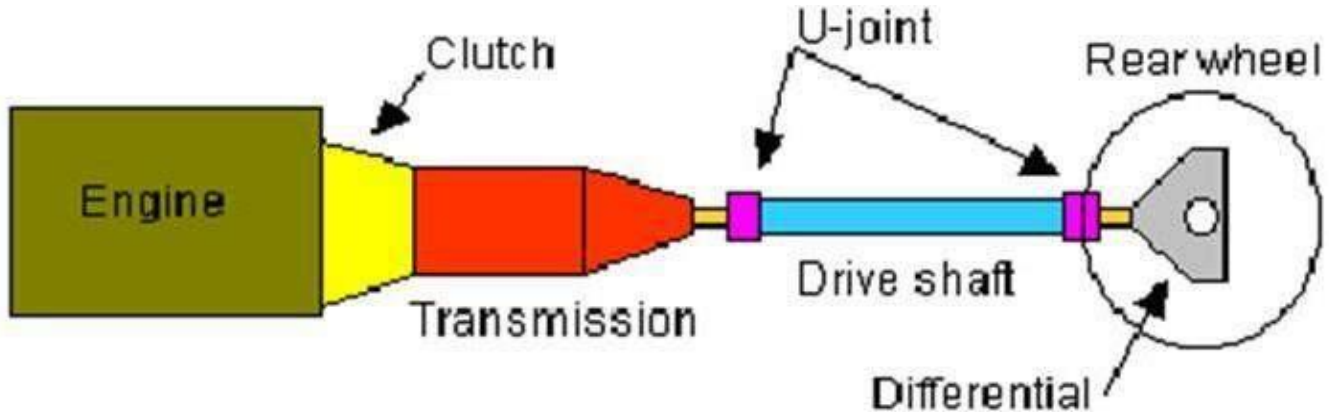
What is Automobile

- A self propelled vehicle that usually has 4 wheels & internal combustion engine used for land transport (people & items).

Components of Automobile

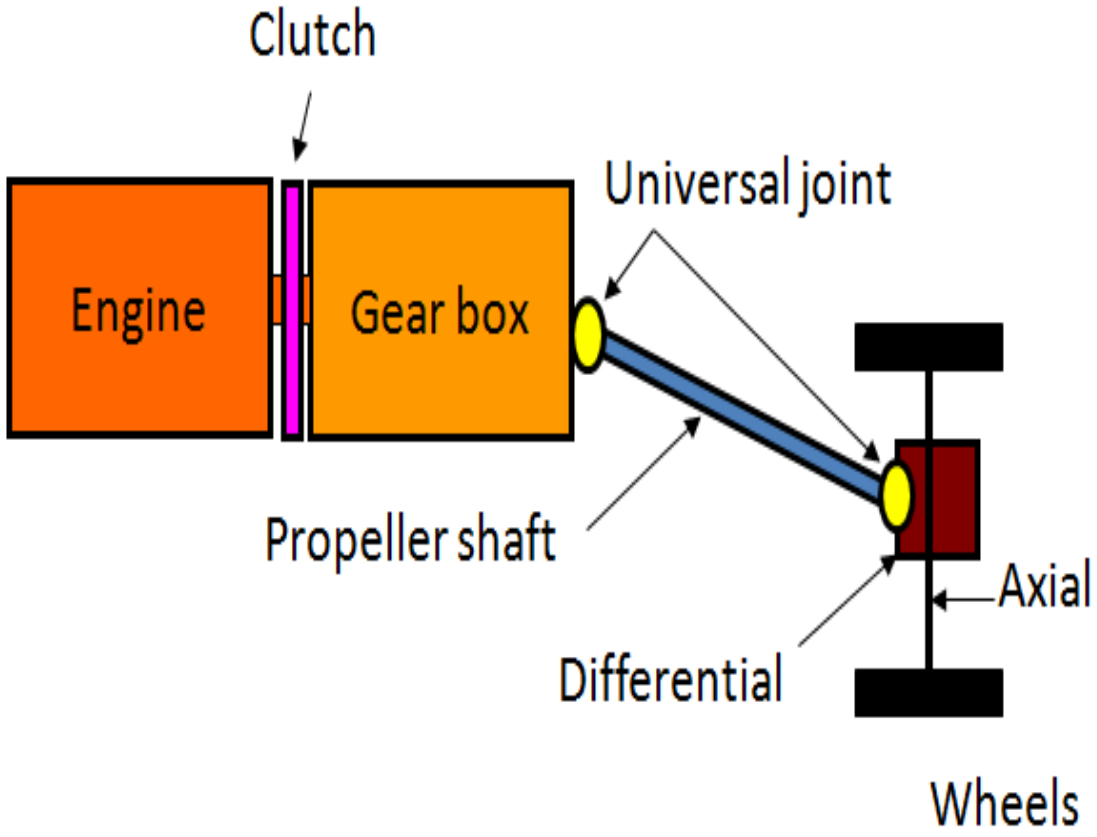
- Basic Structure
- Power plant
- Transmission system
- Auxiliaries
- Controls
- Superstructure



Transfer power from engine to wheels

TRANSMISSION

- Clutch
- Gear box
- Universal joints
- Propeller shaft
- Differential gears
- Axial
- Wheel



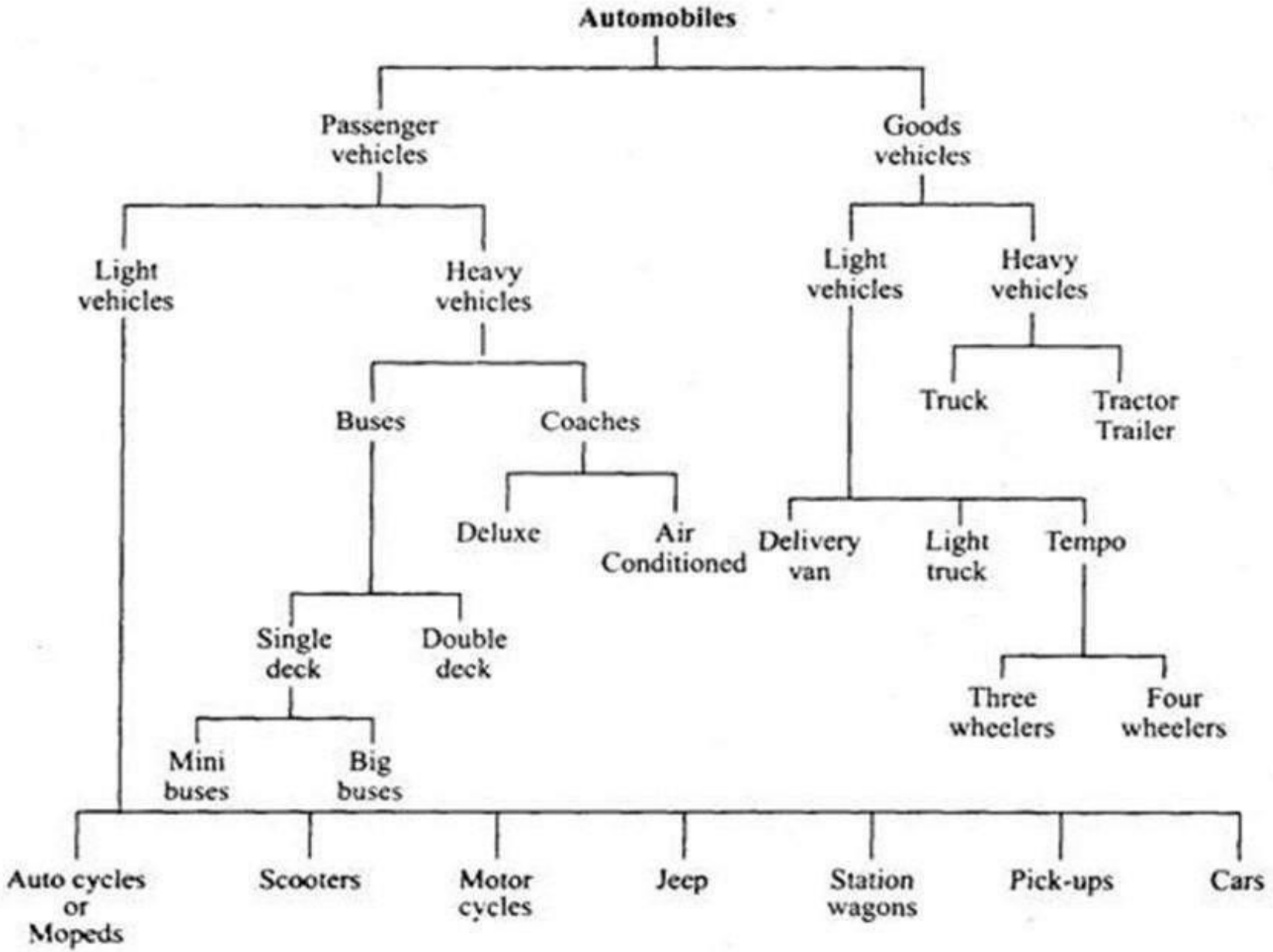
POWER TRAIN

Classification of Automobile

1. Purpose:

- Passenger carriers:

- Good carriers:


Automobiles
Passenger vehicles
Goods vehicles
Light vehicles
Heavy vehicles
Light vehicles
Heavy vehicles
Buses
Coaches
Truck
Tractor Trailer
Deluxe
Air Conditioned
Delivery van
Light truck
Tempo
Single deck
Double deck
Three wheelers
Four wheelers
Mini buses
Big buses
Auto cycles or Mopeds
Scooters
Motor cycles
Jeep
Station wagons
Pick-ups
Cars

Classification of Automobile

2. Capacity:

- heavy transport vehicles (H.T.V) like truck & buses.
- Light transport vehicles (L.T.V) like cars, jeeps etc.

3. Fuel used:

- petrol vehicles
- Diesel vehicles
- Gas vehicles
- Electric vehicle

4. wheels:

- Two wheelers like scooters, motor cycles etc.
- Three wheelers like autorickshwas, tempo.
- Four wheelers like cars, jeeps.
- Six wheelers like trucks, bus.

5. Body style:

- Closed cars like: saloon, coupe etc.
- Open cars like sports car, convertible car.
- Special style such as estate car, station wagon etc.

6. Drive:

- Left hand drive e.g. vehicles use in U.S.A
- Right hand vehicle e.g. Indian vehicles.
- Front wheel drive
- Rear wheel drive
- All wheel drive

7. Transmission:

- Manual
- Semi automatic
- Fully automatic

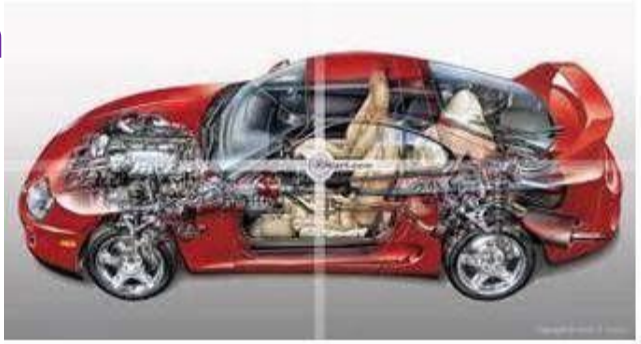
8. Suspension:

- Conventional: Leaf spring

- Independent: Coil springs, Pneumatic.

9. Position of engin

- Engine in front



- Engine inside driver's cabine

- Engine in rare side

Parts of Automobile

- Machine portion: Chassis
- Carriage portion: Body

Automobile = Chassis + Body

- Body (carriage portion): portion of an automobile where passengers have their seats or where cargo to be carried is placed.
- Chassis (machine portion): contains almost all the parts of an automobile which are necessary to drive vehicles.

Machine Portion

- Every automobile consists of four basic units:

➢ Chassis

➢ Transmission

➢ Engine

➢ Electrical equipments

Transmission

- This unit transmits the power from the engine to the wheels.
- Consists of:
  - Clutch
  - Gear box
  - Final drive
  - Axles & differential.

Engine :

- Engine is the source of power.
- Consists of following basic system:
  - Fuel system
  - Ignition system
  - Lubrication system
  - Cooling system

Electrical system

- Consists of:
  - Battery
  - Alternators
  - Ignition system
  - Lightening system

Chassis

- This part of an automobile supports its body, engine & transmission system.
- The chassis contains all the major units necessary to propel the vehicle, direct its motion, stop it, and allow it to run smoothly over uneven surfaces.

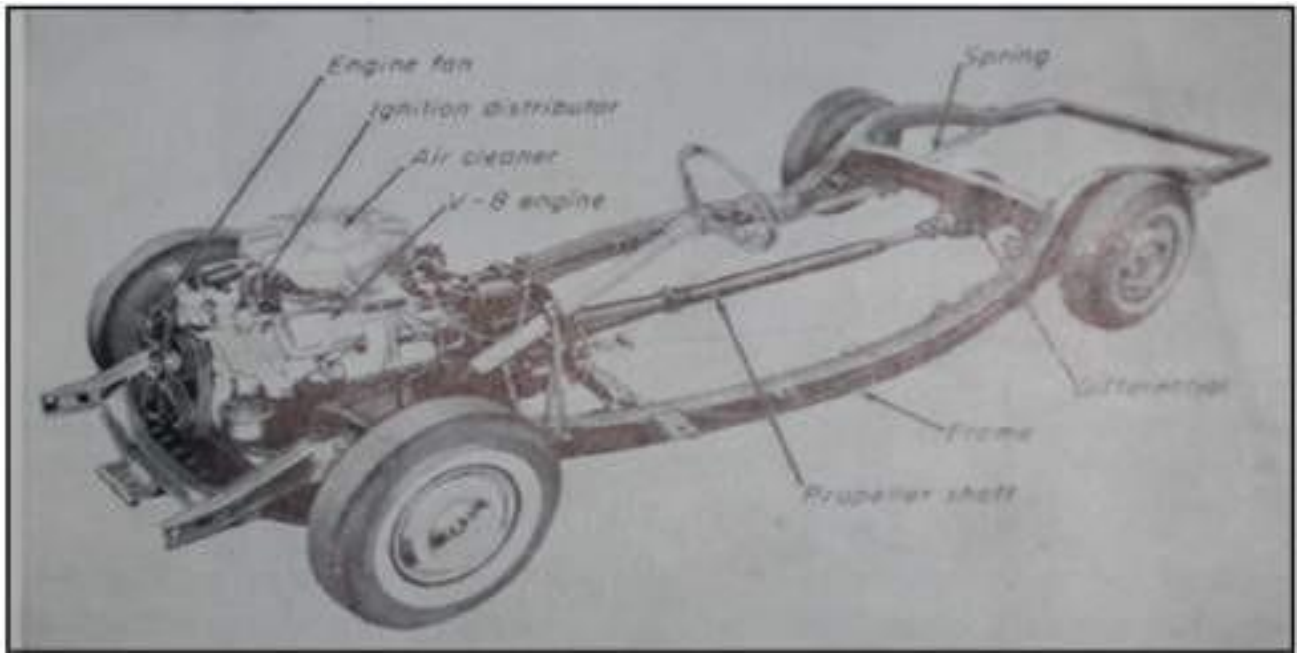
- The chassis of an automobile consists of the following components suitably mounted:

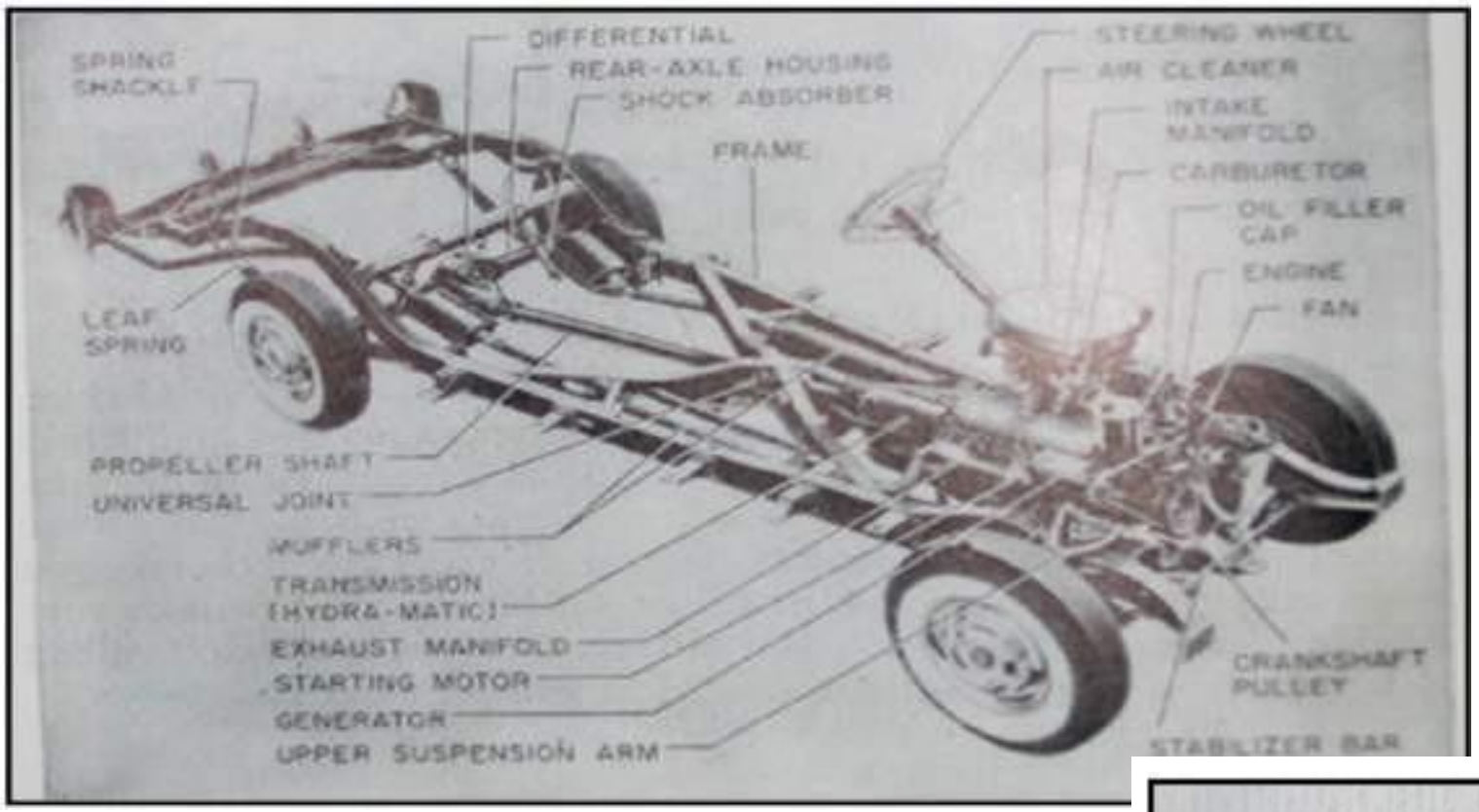
  (i) Frame (ii) Front axle (iii) Steering system (iv) Rear-axle (v) Suspension system (vi) Transmission (vii) Brake system (viii) Engine (ix) Electrical system. The chassis is sub-divided into (i) Power plant (ii) Running gear.

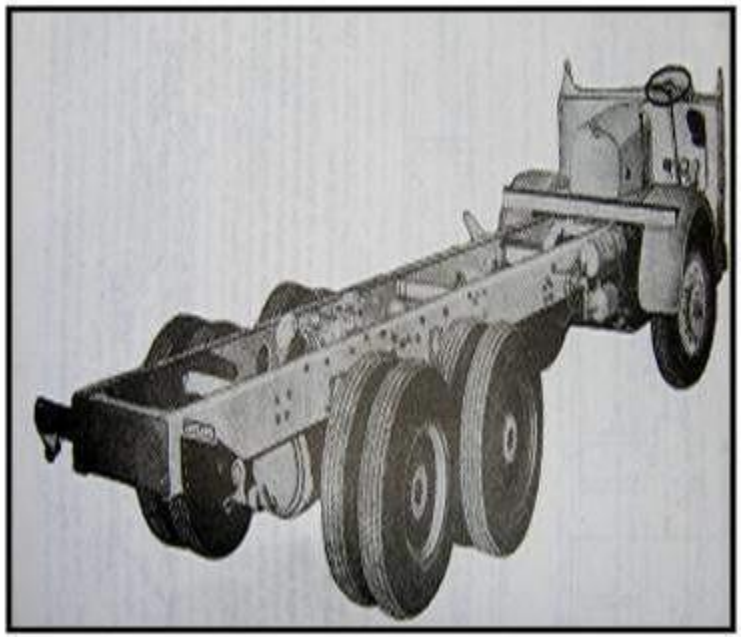
Chassis

All the above mentioned components are mounted in either of the following two ways :

1. Conventional construction: In this case a separate frame is used.
2. Frameless or unitary construction: Here no separate frame is employed.




SPRING SHACKLE
DIFFERENTIAL
REAR-AXLE HOUSING
SHOCK ABSORBER
FRAME
STEERING WHEEL
AIR CLEANER
INTAKE MANIFOLD
CARBURETOR
OIL FILLER CAP
ENGINE
FAN
LEAF SPRING
PROPELLER SHAFT
UNIVERSAL JOINT
MUFFLERS
TRANSMISSION (HYDRA-MATIC)
EXHAUST MANIFOLD
STARTING MOTOR
GENERATOR
UPPER SUSPENSION ARM
CRANKSHAFT PULLEY
STABILIZER BAR

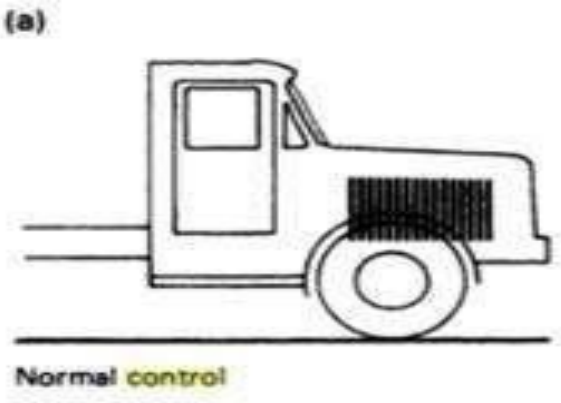


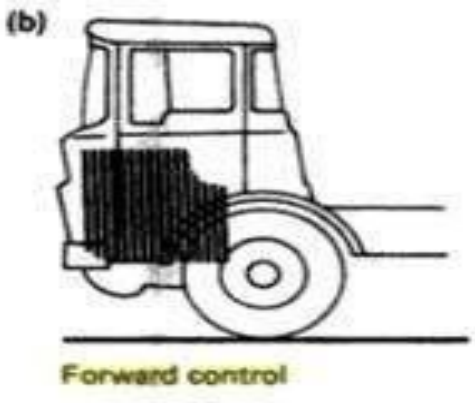
Chassis Classification

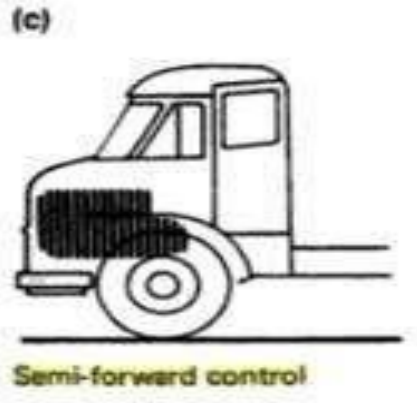
(i) Conventional chassis : In this type of chassis, engine is fitted in front of the driver cabin or driver seat such as in cars and previous model of Tata trucks. Here, the driver sits behind the engine (i.e., quite far off from the front axle) and as such he cannot see the road just in front of the front tyres. Owing to this reason slope is provided at the mudguard and bonnet to enable the driver to see close to the wheels as far as possible.

(ii) Semi-forward chassis : This is such a chassis where half portion of the engine is in the driver cabin and remaining half is outside the cabin such as in Standard. Bedford Pick-ups and Tab a trucks.

(iii) Full-forward (or Bus) chassis : In this type of chassis the complete engine is mounted inside the driver cabin.







Types of Chassis Layout

- Based on:

➢ Types of drive:

(i) Front Wheel Drive

(ii) Rear Wheel Drive

(iii) Four Wheel Drive

➢ Power plant location:

(i) Engine at front

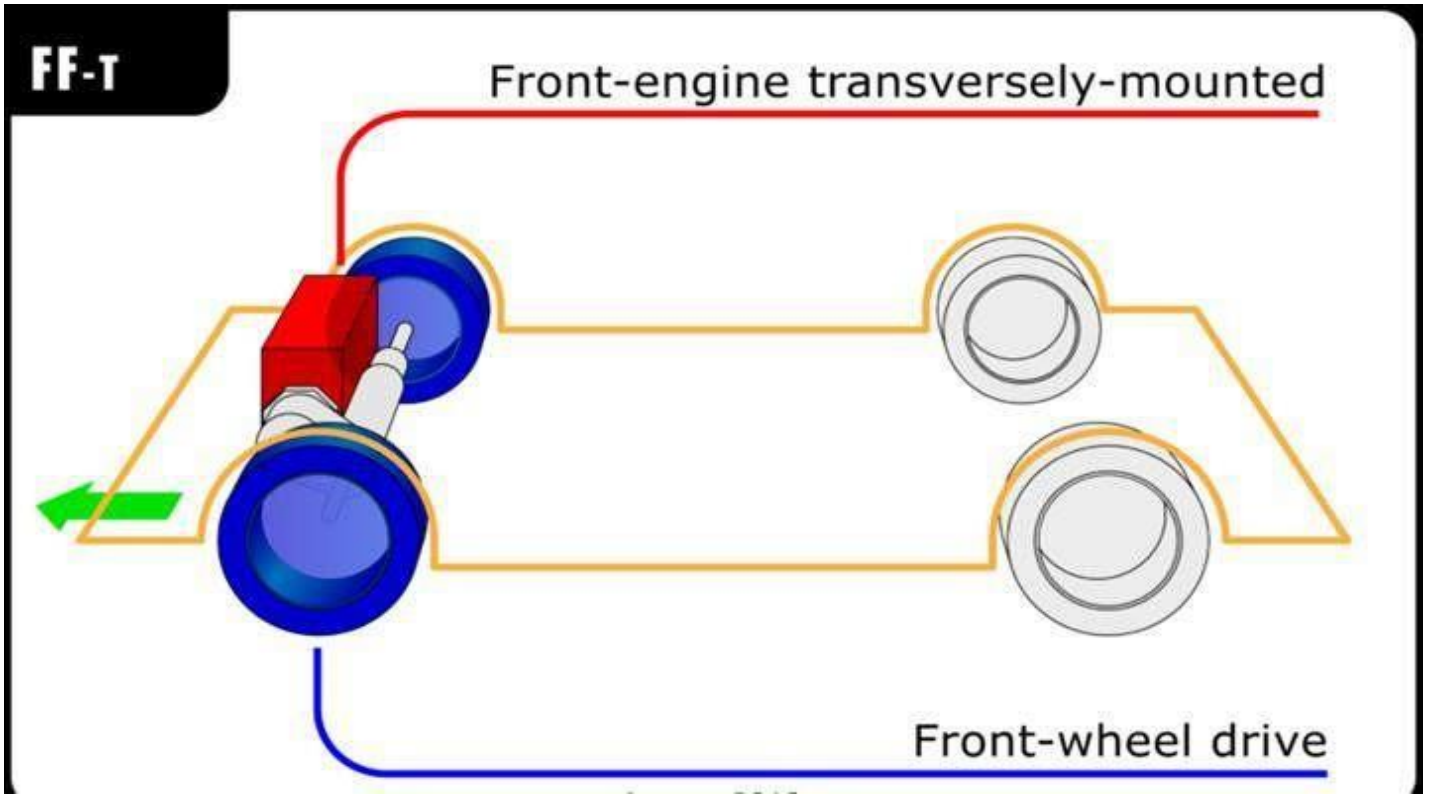
(ii) Engine fitted in front but crosswise

(iii) Engine fitted at the centre of the chassis

(iv)) Engine fitted at the back

Front Wheel Drive Layout

- Front wheel drive layout are those in which the front wheels of the vehicle are driven.
- Generally considered superior to FR (front-engine, rear-wheel-drive layout) cars in conditions such as snow, mud.
- Audi A3 , Audi A4 and Audi A6.



Advantages of Front Wheel Drive

- Interior space: no need to devote interior space for a driveshaft tunnel or rear differential, increasing the volume available for passengers and cargo.
- Weight: Fewer components.
- Fuel Efficiency: Improved fuel efficiency due to less weight.
- Cost: Less material
- Improved drive train efficiency: direct connection between engine and transaxle reduce the mass and mechanical inertia of the drive train.
- Improved Traction & Stability: On wet, snowy, or icy surfaces.

Disadvantages of Front Wheel Drive

- Nose heavy (more weight distribution forward): which makes them prone to understeer especially in high horse power applications.

- High Turning circle: almost always use a Transverse engine installation, which limits the amount by which the front wheels can turn, thus increasing the turning circle of a front-wheel-drive car compared to a rear-wheel-drive one with the same wheelbase.

- Size of the engine: FE transverse engine layout (also known as "east-west") restricts the size of the engine that can be placed in modern engine compartments, so it is rarely adopted by powerful luxury and sports cars.

Disadvantages of Front Wheel Drive

- FE configurations can usually only accommodate Inline-4 and V6 engines, while longer engines such as Inline-6 and 900 big-bore V8 will rarely fit.
- Heavier use of the front tires: it makes heavier use of the front tires causing more wear in the front that in a rear wheel drive layout

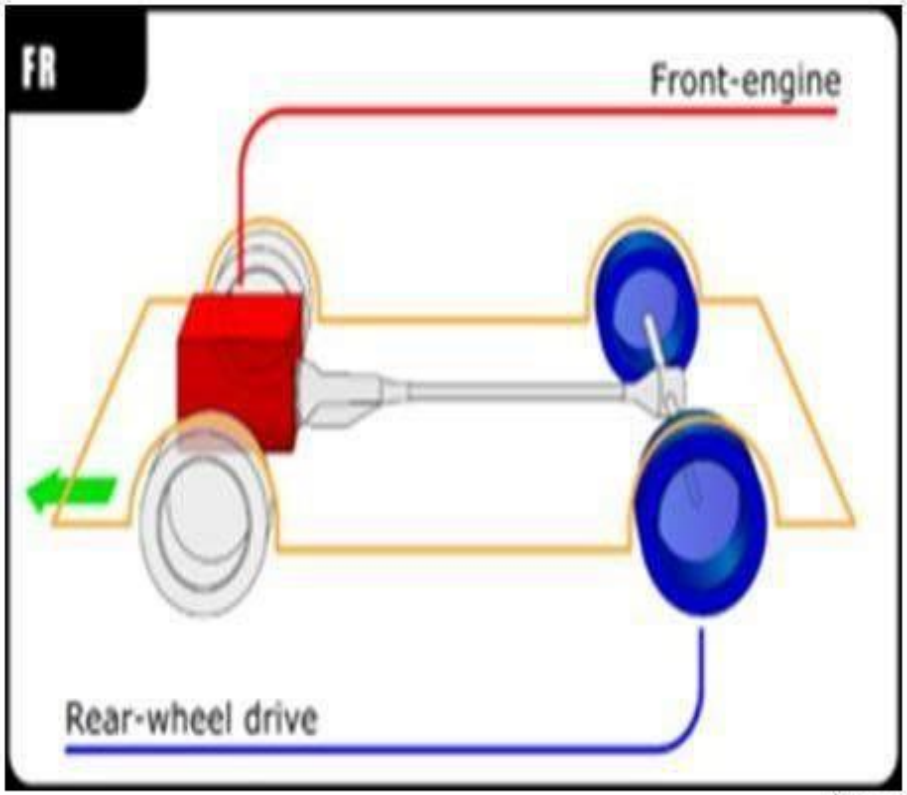
HYUNDAI i10 iRDE

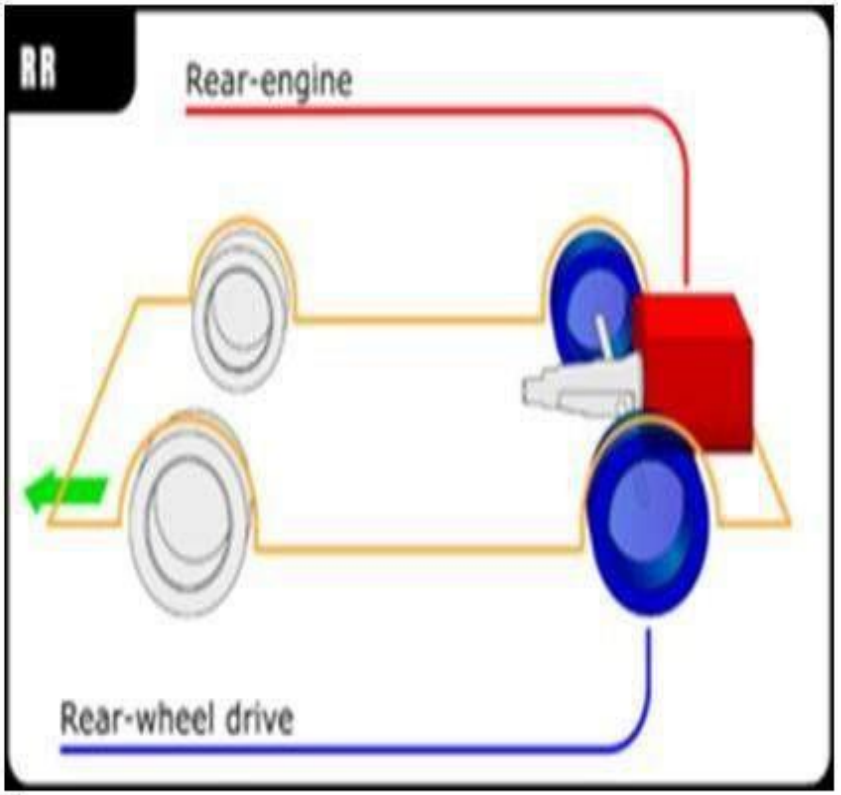
Engine 1086cc, 67PS, 98Nm
Transmission Five-speed manual, front-wheel drive
Performance 15.5 secs 0-100km/h,
Fuel efficiency 14.9kmpl (overall)

intelligent responsive drive engine

Rear Wheel Drive Layout

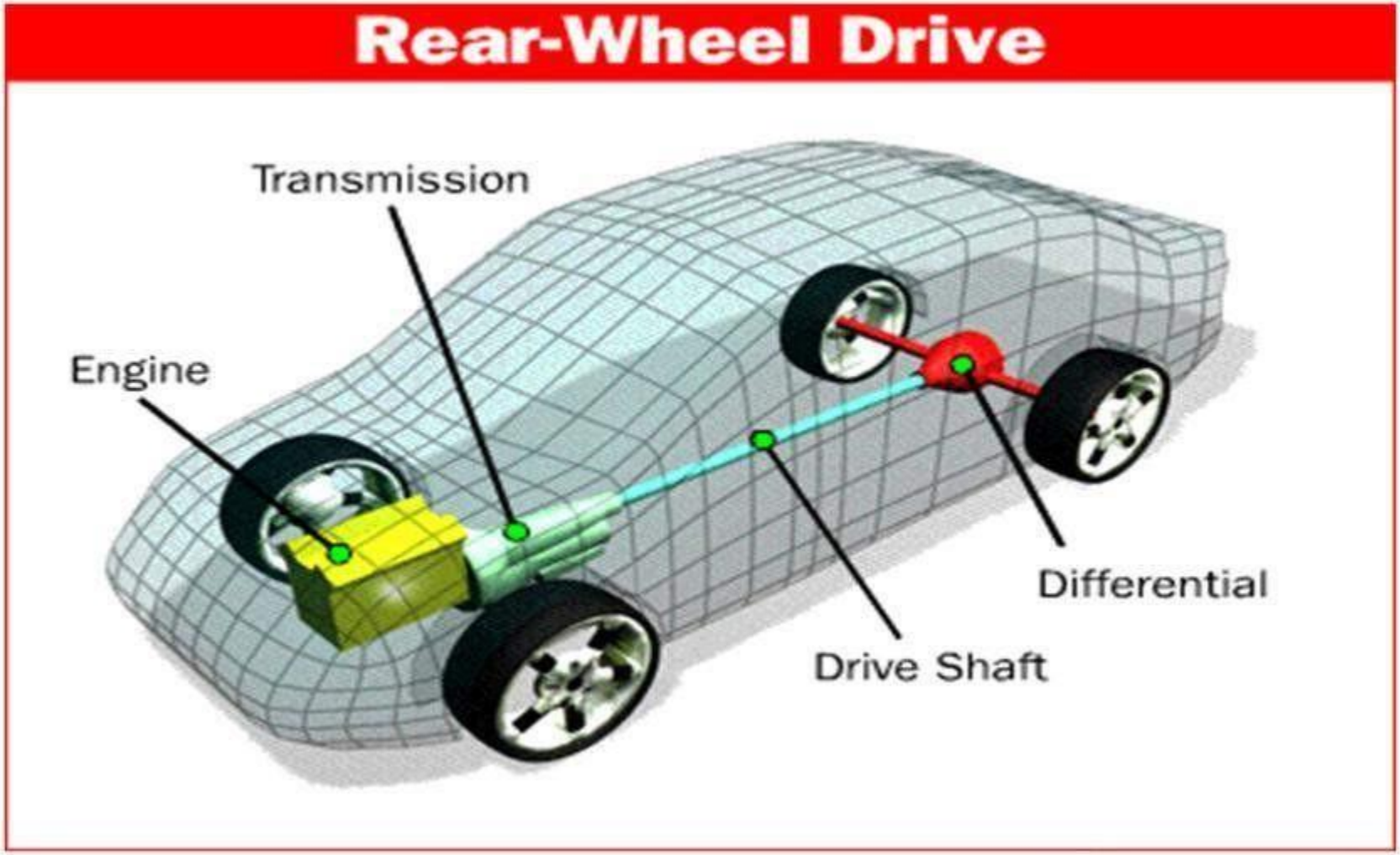
- Rear wheel drive typically places the engine in the front of the vehicle and the driven wheels are located at the rear a configuration known as front engine, rear wheel drive layout (FR layout).





Rear Wheel Drive Layout

- FR layout is often chosen for its simple design & good handling characteristics.



Rear Wheel Drive Layout

Volkswagen Beetle

VW New Beetle

RR Layout

5 generation BMW 3-Series

Rear wheel drive

Advantages of Rear Wheel Drive Layout

- Even weight distribution
- Turning radius As no complicated drive shaft joints are required at the front wheels, it is possible to turn them further than would be possible using front-wheel drive, resulting in a smaller steering radius for a given wheelbase.
- Better handling the more even weight distribution and weight transfer improve the handling of the car.
- Can accommodate more powerful engines as a result of the longitudinal orientation of the drivetrain, such as the Inline-6, 90° big-bore V8, V10 and V12 making the FR a common configuration for luxury and sports cars.

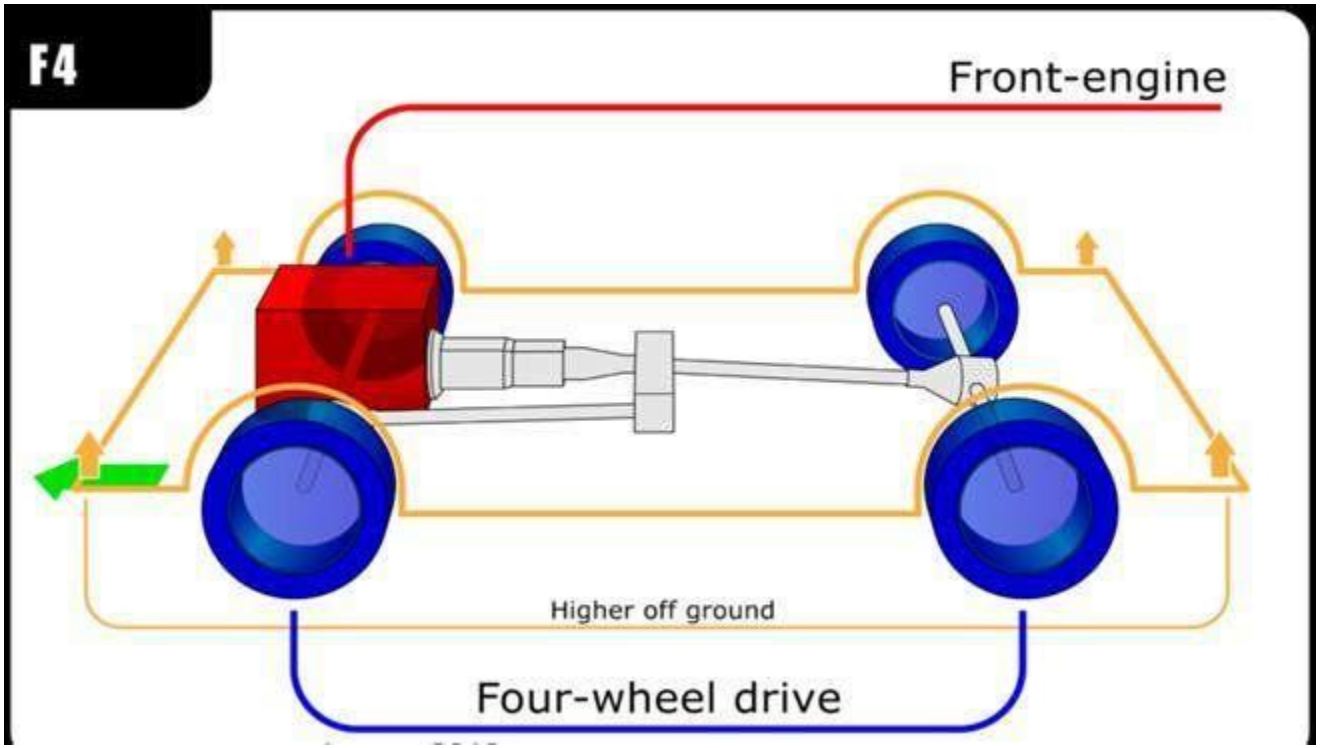
Disadvantages of Rear Wheel Drive Layout

- On snow, ice and sand, rear-wheel drive loses its traction advantage to front- or all-wheel-drive vehicles, which have greater weight on the driven wheels.
- Increased weight The components of a rear-wheel-drive vehicle's power train are less complex, but they are larger.
- Cost of materials and Increased complex assembly of FR layouts.
- Low Mechanical Efficiency- The possibility of a slight loss in the mechanical efficiency of the drivetrain (approximately 17% losses between engine flywheel and road wheels compared to 15% for front-wheel drive)

Body style	4-door saloon
Layout	FR layout
Transmission	5-speed manual

Four wheel drive layout (all wheel drive)

- Most 4WD layout are front engined and are derivatives of earlier front engine, two wheel drive designs.



Four wheel drive layout (all wheel drive)

- Four-wheel drive, All-wheel drive, AWD, 4WD, or 4x4 ("four by four") is a four-wheeled vehicle with a drivetrain that allows all four wheels to receive torque from the engine simultaneously.

- 4x2 a four-wheel vehicle that transmits engine power to only two axle-ends: the front two in front-wheel drive or the rear two in rear-wheel drive.

Murciélago (M4)

Humvee (HMMWV)

High Mobility Multipurpose Wheeled Vehicl

Subaru Impreza (rally car)

Advantages of Four wheel Drive

- High Traction: Traction is nearly doubled compared to a two-wheel-drive layout.
- Better Weight Distribution: Because additional components are needed to transfer power to the rear wheels, more of the vehicle's weight is located toward the rear. This balances the weight of the engine, which makes all front-wheel drive vehicles heavier in the front.
- Off-Road Capability: Many trucks and SUVs intended for off-road use feature all-wheel or four-wheel drive systems. This allows them to drive over uneven terrain where one or more wheels may come away from the road surface where that cannot provide traction.
- The vehicle can continue to move as long as there is sufficient contact between the road surface and other drive wheels. These all-wheel drive vehicles are also more capable of moving on muddy surfaces.

Disadvantages of Four wheel Drive

- Complex Machinery & Transmission: require more machinery and complex transmission components, and so increase the manufacturing cost of the vehicle and complexity of maintenance procedures and repairs compared to 2WD designs.

- Stopping Distance: While the weight of 4WD vehicles improves their handling, it also increases the distance they require to stop.

- Poor performance in ideal dry conditions: 4WD systems increase power-train mass, rotational inertia and power transmission losses, resulting in a reduction in performance in ideal dry conditions and increased fuel consumption compared to 2WD designs.

Power Plant Location

(i) Engine at front:

(a) conventionally the engines are fitted at front & drive is given to the wheels from the rear.

(b) In another arrangement the engine is fitted in front & drive is also given to the front wheels only as in matador vehicles.

(ii) Engine fitted in front but crosswise: in this arrangement the engine is fitted in front not in conventional way but crosswise as in maruti, B.M.C mini & drive is given to the front wheels only.

(iii)Engine fitted at the centre of the chassis : •In this case, the engine is fitted at the centre of the chassis i.e., under the chassis as in Royal Tiger World master buses previously plied by Delhi Transport Corporation.

(iv) Engine fitted at the back : shows a rear engine drive. Popular vehicles, employing this system are Renault, Dolphin and Volkswagon, where engine is fitted at the rear of the vehicle.

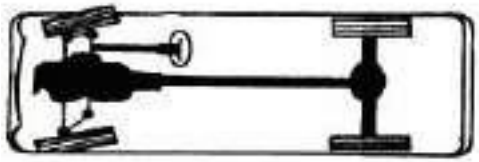


Fig. Conventional drive.

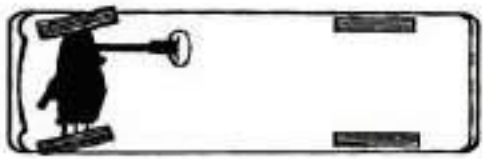


Fig. Front engine drive.

Fig. Centre engine drive.

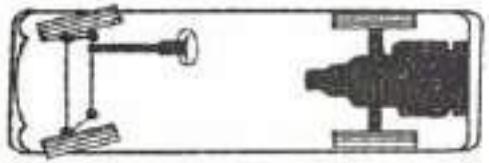


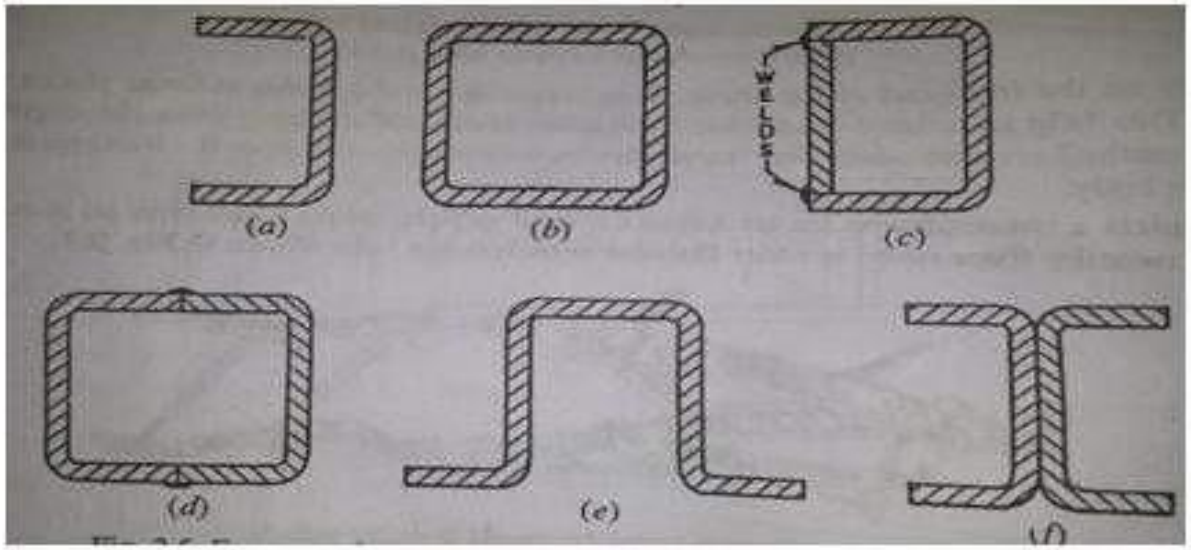
Fig. Rear engine drive.

Frame

- Function of the frame:

1. To support the chassis components & the body.
2. To understand static & dynamic loads without undue deflection or distortion.

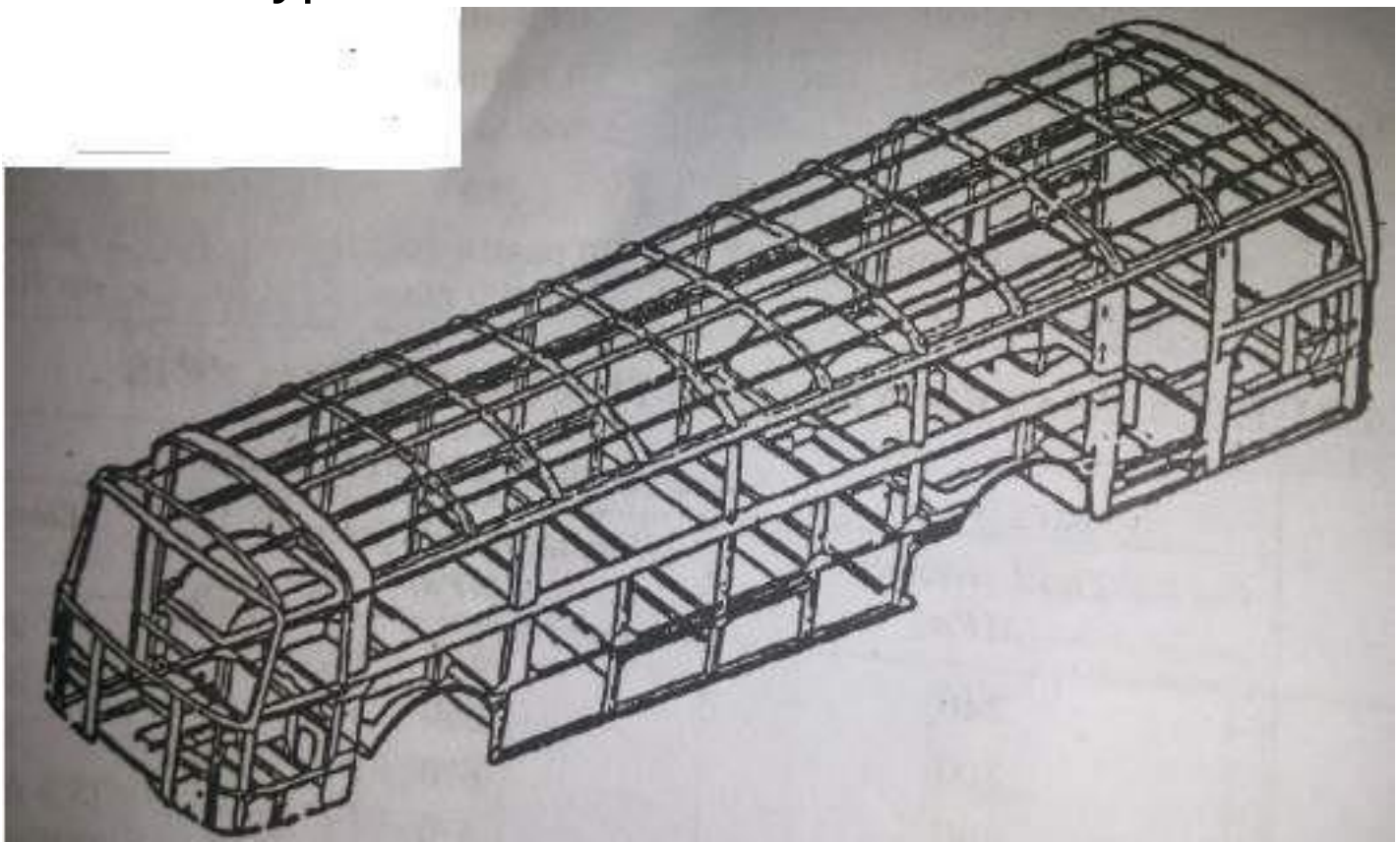
Frame sections



(a) Channel section (b), (c), (d) box section (d) hat section (e) double channel or I section

Frameless Construction

- In this type of construction heavy sides members used in conventional construction are eliminated & the floor is strengthened by cross members & the body all welded together. In some cases the sub frames are also used along with this type of construction.



Need of clutch

- In a car, you need a clutch because by controlling the slippage between them the engine spins all the time, but the car's wheels do not. In order for a car to stop without killing the engine, the wheels need to be disconnected from the engine somehow. The clutch allows us to smoothly engage a spinning engine to a non-spinning transmission.

- A clutch works because of friction between a clutch plate and a flywheel.

Clutch

- In Automobiles, the clutch is used to engage or disengage the engine with the transmission system. It enables the rotary motion of one shaft to be transmitted to the second shaft as and when required.

- The clutch should be able to transmit the maximum torque. It should take drive gradually. During clutch application, the heat generated by the friction of clutch surfaces should be dissipated. During high speeds the clutch should be balanced.

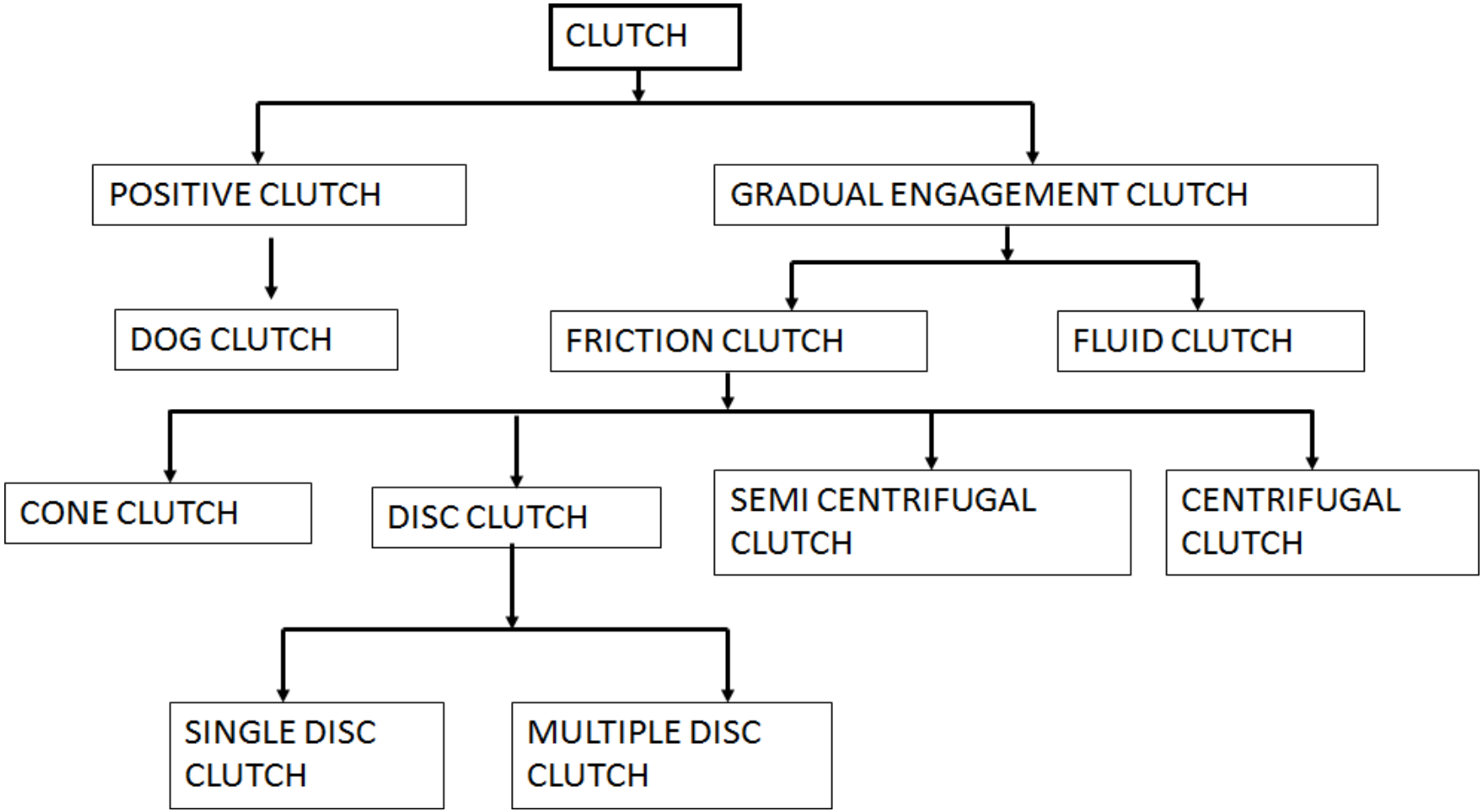
Requirements of Clutch

- Torque transmission: The clutch should be able to transmit the maximum torque of the engine under all condition. It is usually designed to transmit 125 to 150 per cent of the maximum engine torque
- Gradual engagement: The clutch should positively take the drive gradually without the occurrence of sudden jerks.
- Heat dissipation: During clutch application, large amounts of heat are generated. The rubbing surfaces should have sufficient area and mass to absorb the heat generated. The proper design of the clutch should ensure proper ventilation or cooling for adequate dissipation of the heat.
- Dynamic balancing: This is necessary particularly in the high speed clutches not be tiresome to the driver.

Requirements of Clutch

- Vibration damping : Suitable mechanism should be incorporated with in the clutch, to eliminate noise produced in the transmission.
- Size: The size of the clutch must be smallest possible so that it should occupy minimum amount of space.
- Inertia : The clutch rotating parts should have minimum inertia. Otherwise, when the clutch is released for gear changing, the clutch plate will keep on spinning, causing hard shifting and gear clashing in spite of synchronizer.
- Clutch free pedal play: To reduce effective damping load on the carbon thrust bearing and wear thereof, sufficient clutch free pedal play must be provided in the clutch.
- Ease of operation: For higher torque transmissions the operation of disengaging the clutch must

Types of clutch



Gradual Engagement Clutches

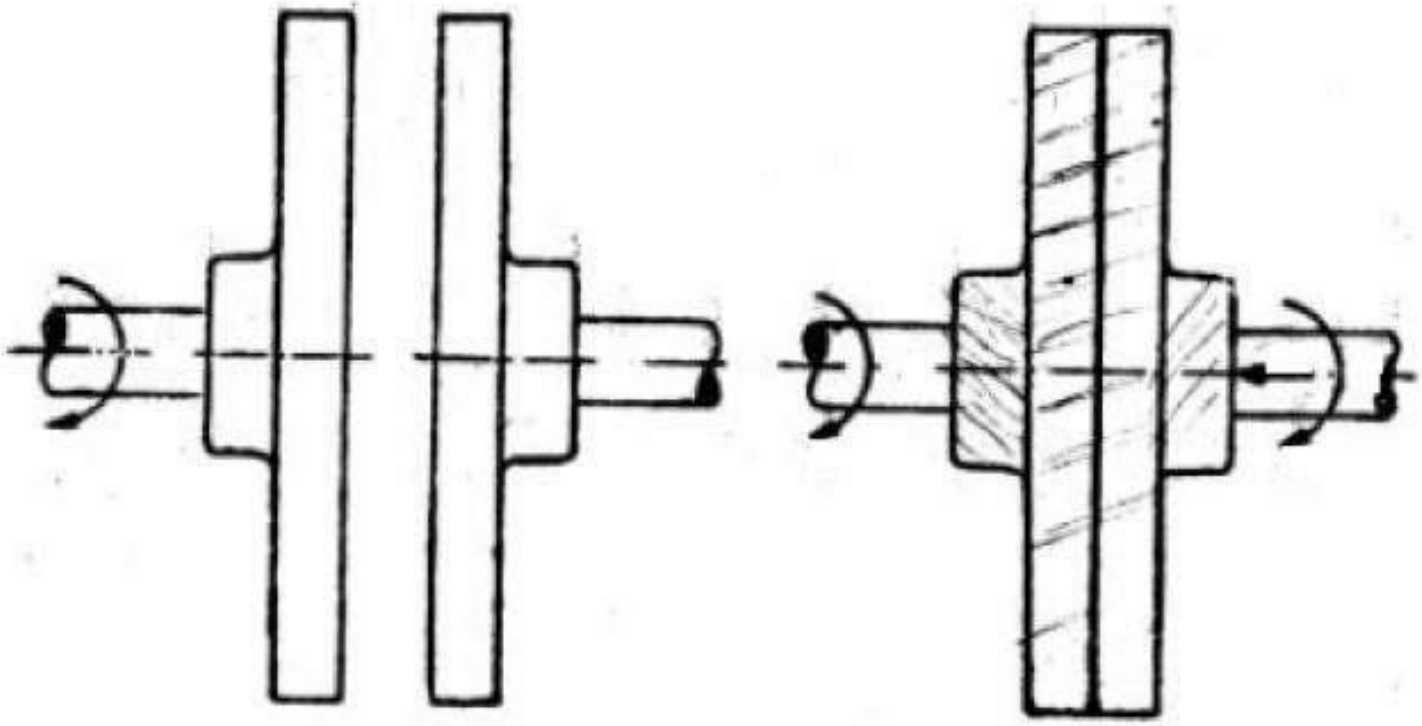
- FRICTION CLUTCHES: Enable the driven member to be disengaged and engaged gradually with the driving member.
- Action depends on the friction force between the members.
- At start low frictional force and increases with the pressing force.
- Pressure exerted by means of coil springs.

• The Torque transmitted by a friction clutch depends upon the factors namely Coefficient of friction (u), Axial pressure (w) and Mean effective Radius of contact surfaces(R).

The Torque Transmitted (T) = μwR.

Basic Principle of Friction Type Clutch

- To understand the working principle of clutch, let's take two discs, first one driven by a power drill corresponds to the flywheel of a car, driven by the engine. If a second sanding disc is brought into contact with the first, friction makes it revolve too but more slowly. But when the second disc pressed against the first disc which is connect to the power drill, as the I pressure increases the two discs revolve as one. This is how a friction clutch works.



Types of friction clutches

a) Cone clutch

b) Single plate clutch

c) Mutilate clutch

d) Semi centrifugal clutch

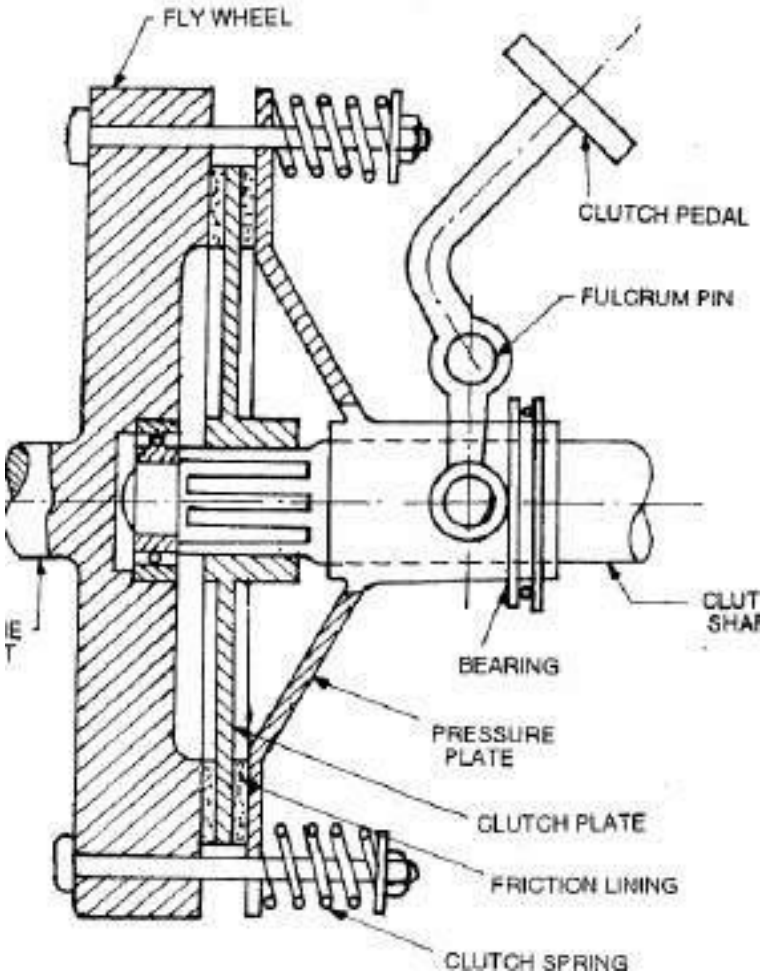
e) Centrifugal clutch.

Construction And Working of Single Plate Clutch

- It is the most common type of clutch used in motor vehicles.
- A single disc or plate clutch consists of a clutch plate whose both sides are faced with a frictional material. It is mounted on the hub which is free to move axially along he splines of the driven (clutch) shaft.
- the pressure plate is mounted inside the clutch body which is bolted to the flywheel.
- Both the pressure plate and the flywheel rotate with the engine crank shaft.
- The pressure plate pushes the clutch plate towards the flywheel by a set of strong springs which are arranged radially inside the body
- When the clutch is engaged, due to the friction between the flywheel, clutch plate and pressure plate, revolves the clutch shaft which is connected to the transmission system also revolves.
- When the clutch pedal is pressed, the pressure plate moves back against the force of the springs, and the clutch plate becomes free between the fly wheel and pressure plate.

Construction and Working of Single Plate Clutch

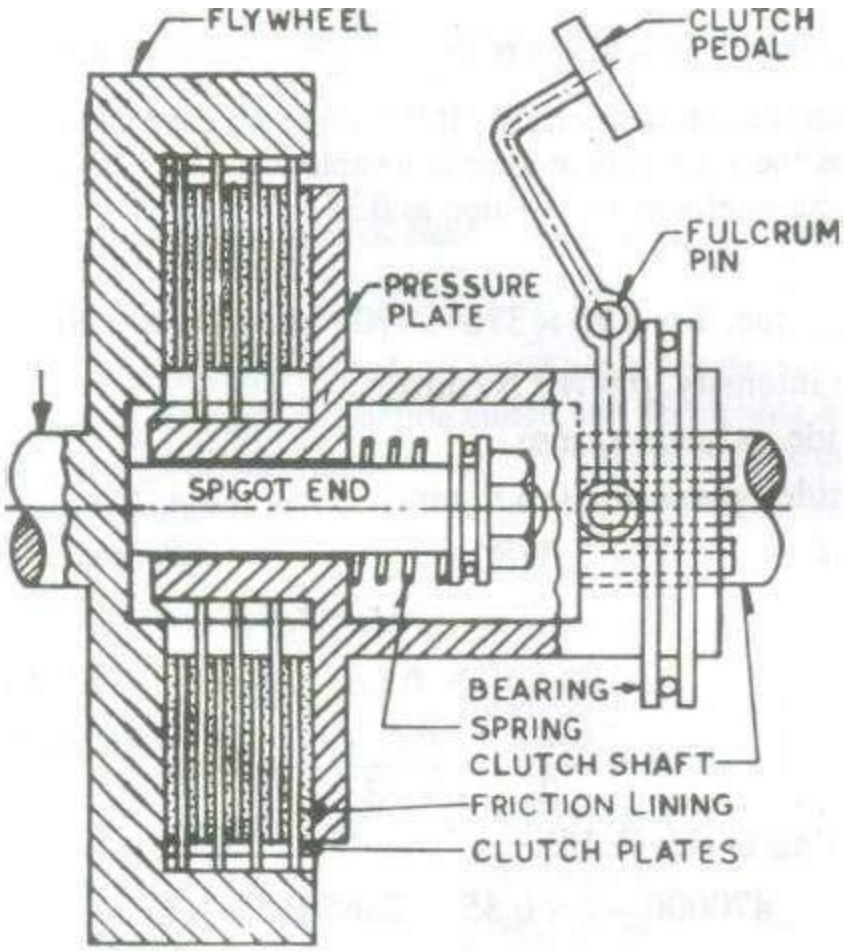
COIL-SPRING CLUTCH

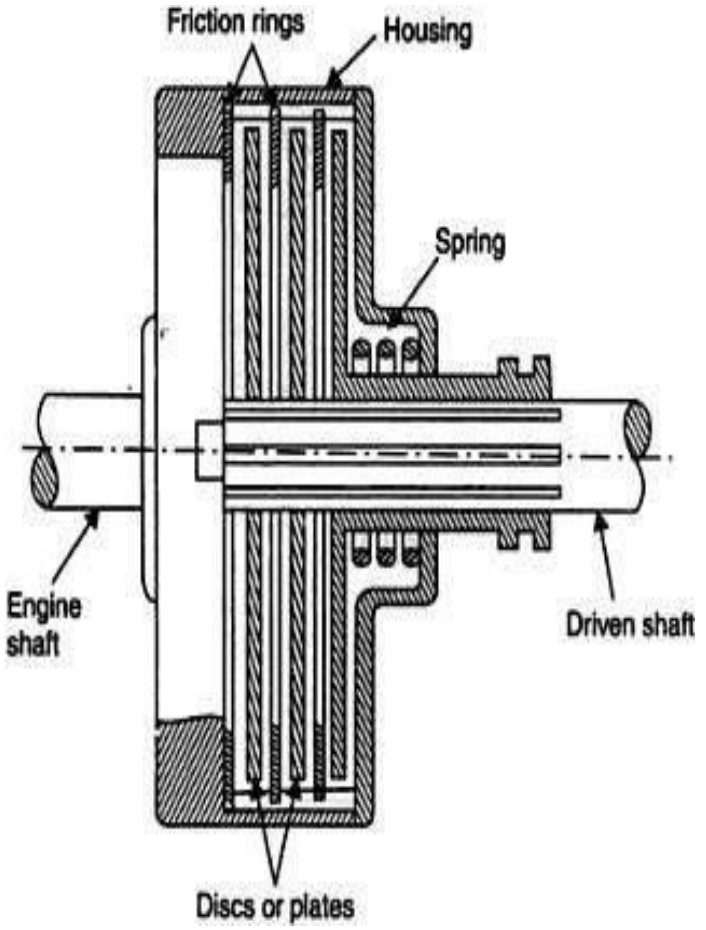


Construction and Working of Multiplate Clutch

- Multi plate clutch consists of a number of clutch plates.
- As the number of clutch plates increased, the friction surfaces also increased.
- the increased number of friction surfaces obviously increases the capacity of the clutch to transmit torque.
- one set of plates slides in grooves on the flywheel and the other set slides on spines on pressure plate hub.
- They are firmly pressed by strong coil springs and assembled in a drum.
- Each of the alternate plate slides in grooves on the flywheel and the other slides on spines on the pressure plate.
- These clutches are used in heavy commercial vehicles, racing cars and motor cycles for transmitting higher torque. Beside these clutches are used in scooters and motor cycles where space available is limited.
- Overall diameter is reduced for the same torque transmission as single plate clutch.

Construction and Working of Multiplate Clutch

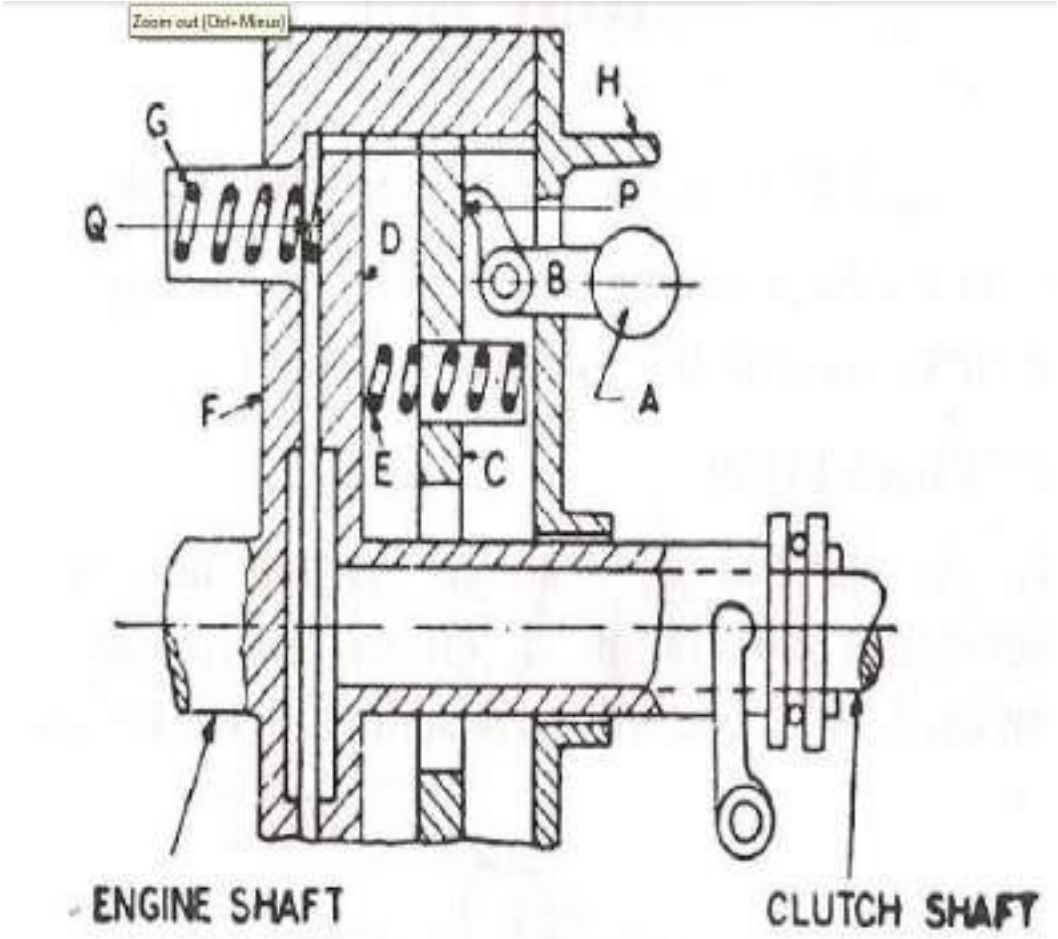




Centrifugal Clutch

- This type of clutch is operated automatically depending upon the engine speed. This means that the vehicle can be stopped in gear without stalling the engine. Similarly while starting, the driver can first select the gear, put the car into the gear and simply press the accelerator pedal. This makes driving operation very easy. This type of clutch is operated by the centrifugal force. This type of clutch is operated automatically depending upon the engine speed. This means that the vehicle can be stopped in gear without stalling the engine. Similarly while starting, the driver can first select the gear, put the car into the gear and simply press the accelerator pedal. This makes driving operation very easy. This type of clutch is operated by the centrifugal force. the bell crank lever 'B' which presses the plate 'C'. This force is transmitted to the plate 'D' by means of springs 'E'. the plate 'D', which contains frictional lining, is thus pressed against the flywheel 'F' there by engaging the clutch. Spring 'G' serves to keep the clutch disengaged at low speed (at about 500 r.p.m). The stop ‘H’ limits the amount of centrifugal force.

Centrifugal Clutch



Cone Clutch

- In this type the contact surfaces are in the form of cones as shown in the figure.
- In the engaged position, the male cone is fully inside the female cone so that the friction surfaces are in complete contact.
- This is done by means of springs which keep the male cone pressed all the time. When the clutch is engaged, the torque is transmitted from the engine via the fly wheel and the male cone to the splined gear box shaft.
- For disengaging the clutch the male cone is pulled out by means of the lever system operated through the clutch pedal thereby separating the contact surfaces.

➢ **Advantage**

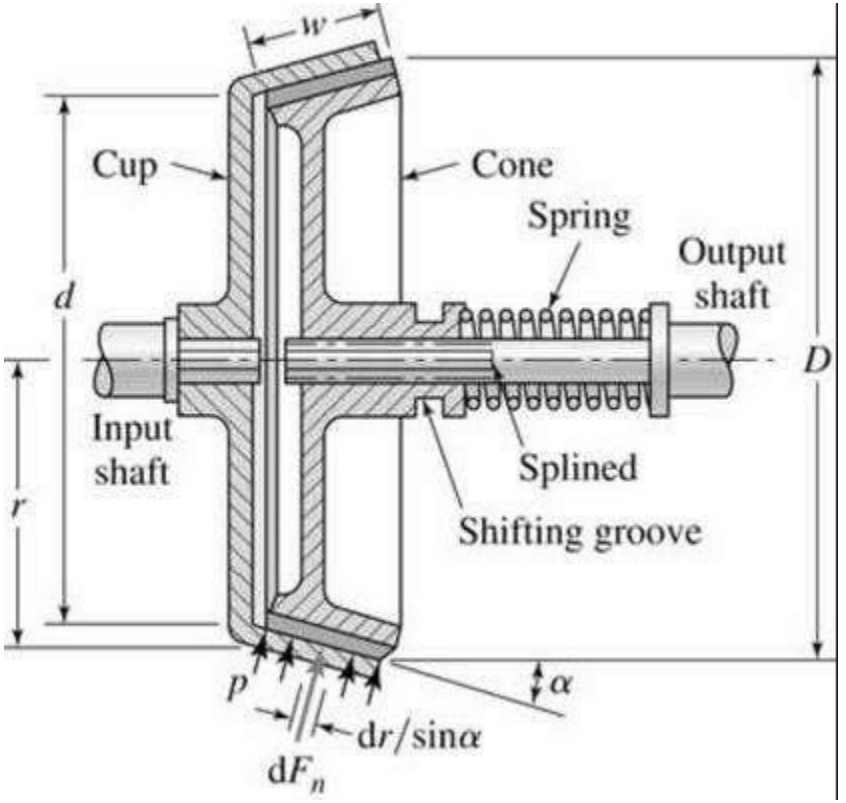
- The only advantage of the cone clutch is that the normal force acting on the contact surfaces in this case is larger than the axial force, as compared to the simple single plate clutch in which the normal force acting on the contact surfaces is equal to the axial force.

Cone Clutch

Disadvantages:

This type of clutch is practically obsolete because of certain inherent disadvantages:

- If the angle of cone is made smaller than about 20° the male cone tends to bind or join in the female cone and it becomes difficult to disengage the clutch.
- A small amount of wear on the cone surface results in a considerable amount of the axial movement of the male cone for which it will be difficult to allow

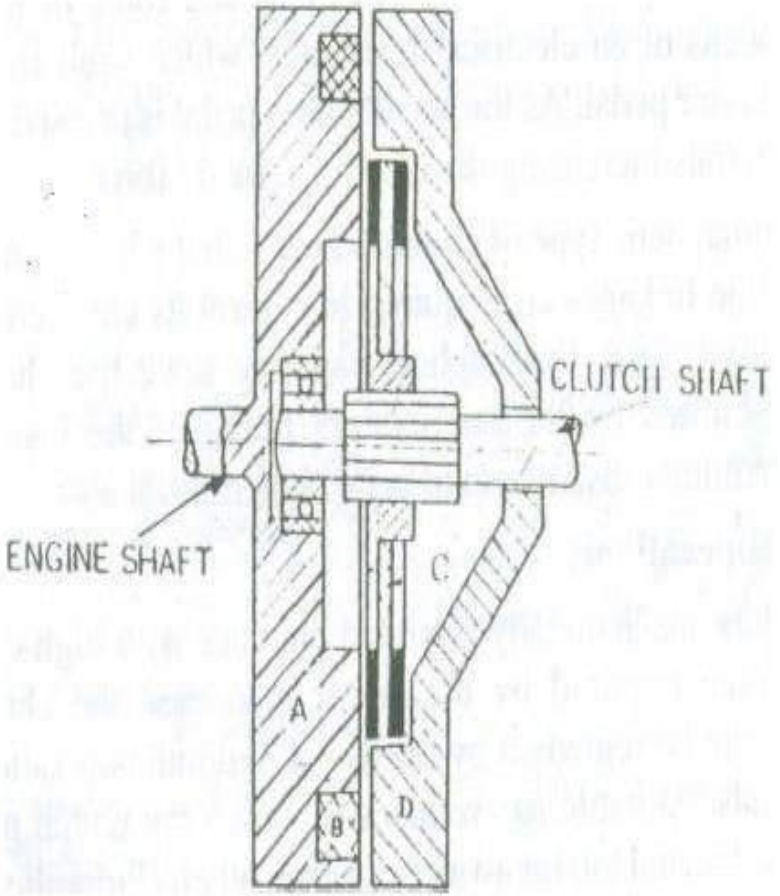


Electromagnetic Clutches

- This type of clutch has been employed on some Renault cars. The construction and working of this clutch may be understood by means of simplified Fig.
- ‘A’ is the engine flywheel incorporating the winding ‘B’. Clutch plate ‘C’ is lined with friction surfaces and is free to slide on splines on the clutch shaft.
- ‘D’ is the pressure plate. The winding ‘B’ is supplied with current from battery dynamo. When the winding ‘B’ is energized, it attracts the pressure plate ‘D’, thereby engaging the clutch.
- When supply to winding ‘B’ is cut off, the clutch is disengaged. There is a clutch release switch in the gear lever. This switch is operated as soon as the driver holds the gear lever to change the gear, cutting off current to the winding and thus causing clutch disengagement.
- Ordinarily the winding is connected to engine dynamo. At lower engine speeds, dynamo output is also low which makes the force in winding very small.

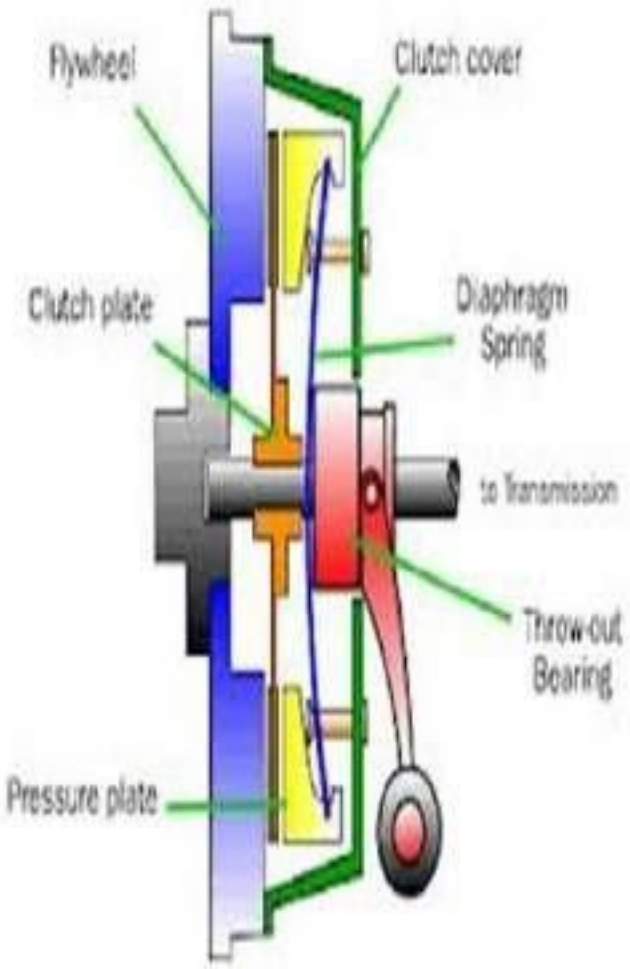
Electromagnetic Clutches

- Three springs are also provided in the clutch (not shown) to balance this reduced electromagnetic force at low speeds, thus disengaging .the clutch.
- During normal operation, the electromagnetic force of the winding is regulated by means of an electrical resistance, which itself is controlled by means of accelerator pedal. As the acceleration pedal is pressed the resistance is gradually cut, thus increasing the electromagnetic force.
- The electromagnetic type of clutch is best suited where remote operation is desired since no linkages are required to control its engagement.
- disadvantage is its higher initial cost.

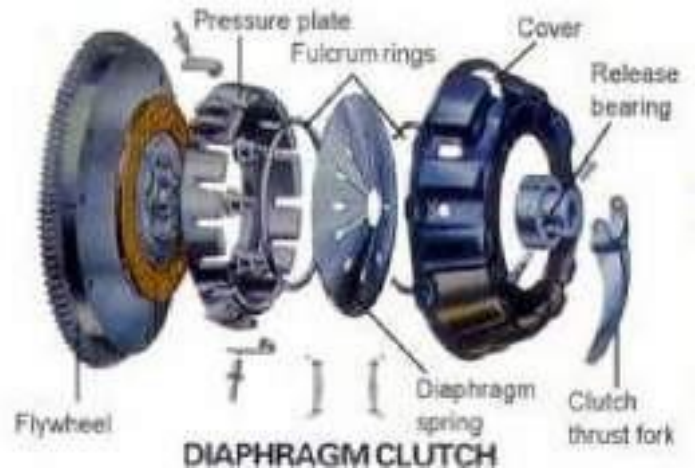


Diaphragm Spring Clutch

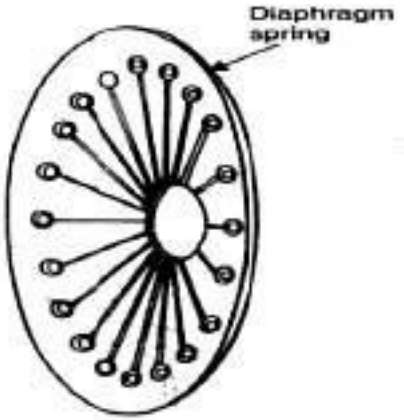
- Diaphragm spring pressure plate assemblies are widely used in most modern cars.
- The diaphragm spring is a single thin sheet of metal which yields when pressure is applied to it.
- When pressure is removed the metal springs back to its original shape.
- The centre portion of the diaphragm spring is slit into numerous fingers that act as release levers.
- During disengagement of the clutch the fingers are moved forward by the release bearing.
- The spring pivots over the fulcrum ring and its outer rim moves away from the flywheel.
- The retracting spring pulls the pressure plate away from the clutch plate thus disengaging the clutch.
- When engaged the release bearing and the fingers of the diaphragm spring move towards the transmission.
- As the diaphragm pivots over the pivot ring its outer rim forces the pressure plate against the clutch disc so that the clutch plate is engaged to the flywheel.



Diaphragm Spring Clutch



DIAPHRAGM CLUTCH



. Diaphragm spring used in diaphragm spring clutch.

ADVANTAGES OF DIAPHRAGM SPRING CLUTCH

1. It is more compact than other designs.
2. It is easier to balance rotationally and is less subjected to unwanted effects due to centrifugal force at high rotational speeds.
3. It gives uniformly distributed pressure on pressure plate.
4. It needs no release levers.
5. Minimum effort is sufficient to disengage the clutch.
6. It provides minimum number of moving components and hence minimum internal friction is experienced.
7. This is very commonly used in cars, light Lorries and mini trucks but is not much used in heavy vehicles

Lining Material

- Clutch linings are a type of friction material; a clutch is used to transfer the motion of one mechanical component to another by keeping two surfaces in contact. The clutch lining is what prevents these two surfaces from slipping.
- Today's clutch linings are usually made from fiberglass, kevlar or some type of metal. Throughout most of the 20th century however, clutch linings were made from asbestos.

➢ Common Clutch Facing Materials:

Organic friction materials are the most common types of clutch facing materials. Examples are :

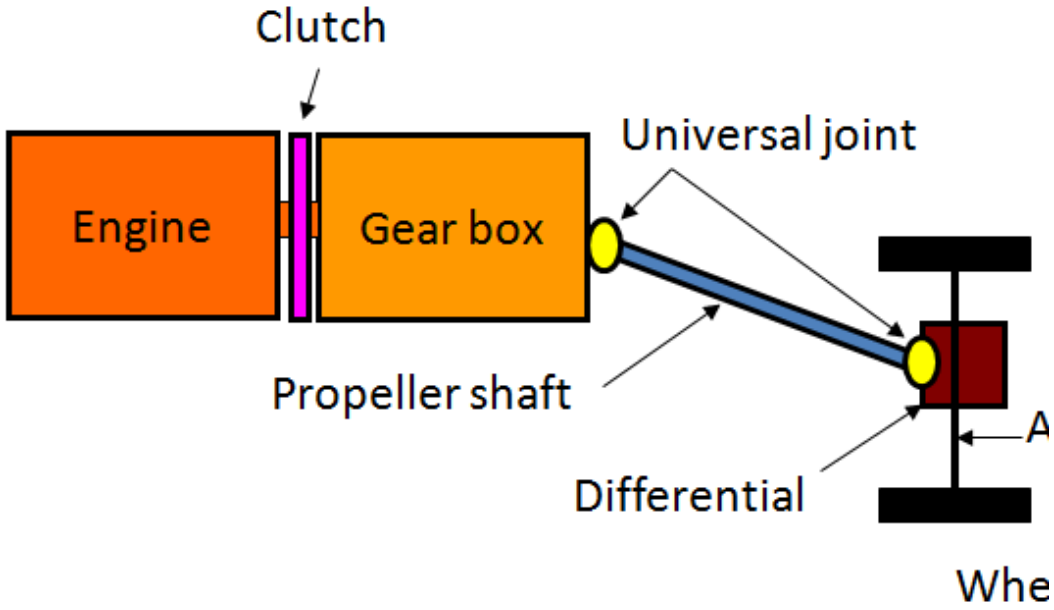
(a) Leather: Dry leather on iron has coefficient in friction of 0.27.
(b) Cork: Cork on dry steel or iron has coefficient of friction of 0.32.
(c) Fabric: Good quality fabric materials have coefficient of friction of about 0.4. But they cannot be used at high temperatures.
(d) Asbestos : Asbestos facing have coefficient of friction of about 0.2. However it has got anti-heat characteristics.
(e) Reybestos and Ferodo: These have a coefficient of friction of about 0.35 and are most suitable as friction facings. They are almost universally used for clutch facings

Clutch Control Systems

1. Pressure Plate
2. Release levers
3. Cover
4. Straps
5. Springs
6. Throwout Bearing

TRANSMISSION SYSTEM

- Clutch
- Gear box
- Universal joints
- Propeller shaft
- Differential gears
- Axial
- Wheel



POWER TRAIN

Necessity of Gear Box

- The gear box is necessary in the transmission system to maintain engine speed at the most economical value under all conditions of vehicle movement. An ideal gear box would provide an infinite range of gear ratios, so that the engine speed should be kept at or near that the maximum power is developed what ever the speed of the vehicle.

- The purpose of gear box is to provide high torque at the time of starting, hill climbing, accelerating and pulling a load. The vehicle will have to face the resistances like wind resistance, gradient resistance and rolling resistance. The tractive effort of the vehicle can be available at various speeds.

Function of Gear Box

- Torque ratio between engine and wheel to be varied for rapid acceleration and for climbing gradient.

- The transmission also provides a neutral position so that the engine & the road wheels are disconnected even with the clutch in the engaged position.

- A means to back the car by reversing the direction of rotation of the drive is also provided by the transmission.

Resistance to Motion of Vehicle

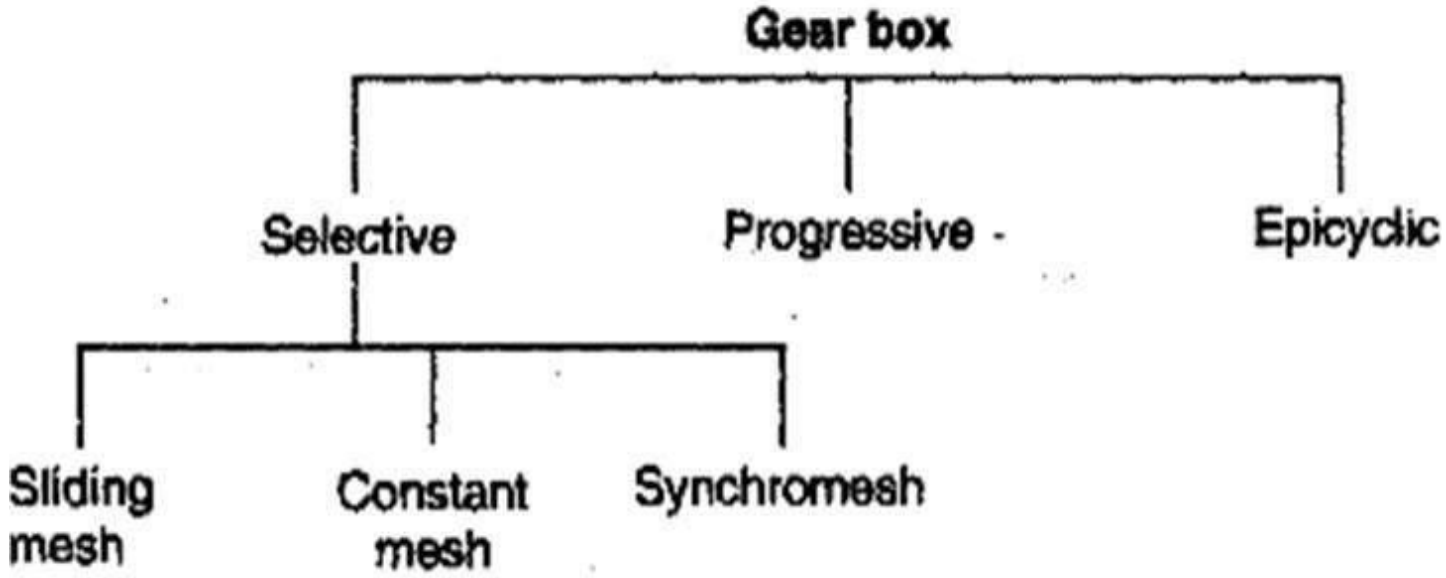
- Total resistance to the vehicle motion consists of:

(i) Resistance due to wind: this is taken to be proportional to the square of the vehicle speed.

(ii) Resistance due to gradient: this remains constant at all speeds. This is the component of the vehicle weight parallel to the plane of the road.

(iii) Miscellaneous: apart from the above two types various other factors also contribute towards the vehicles resistance. These are: type of the road, tyre friction etc.

Types of Gear Box



Selective Type Gear Box

- In this type of transmission, neutral position has to be obtained before selecting any forward or reverse position.

➢ Advantages:

- Simple in construction.
- Less maintenance
- Light & small
- Low production cost.

➢ Disadvantages:

- Noisy in operation
- Gear ratio not being continuous but being in steps (3 to 5 steps), making it necessary to shift gears each time when vehicle running condition change.

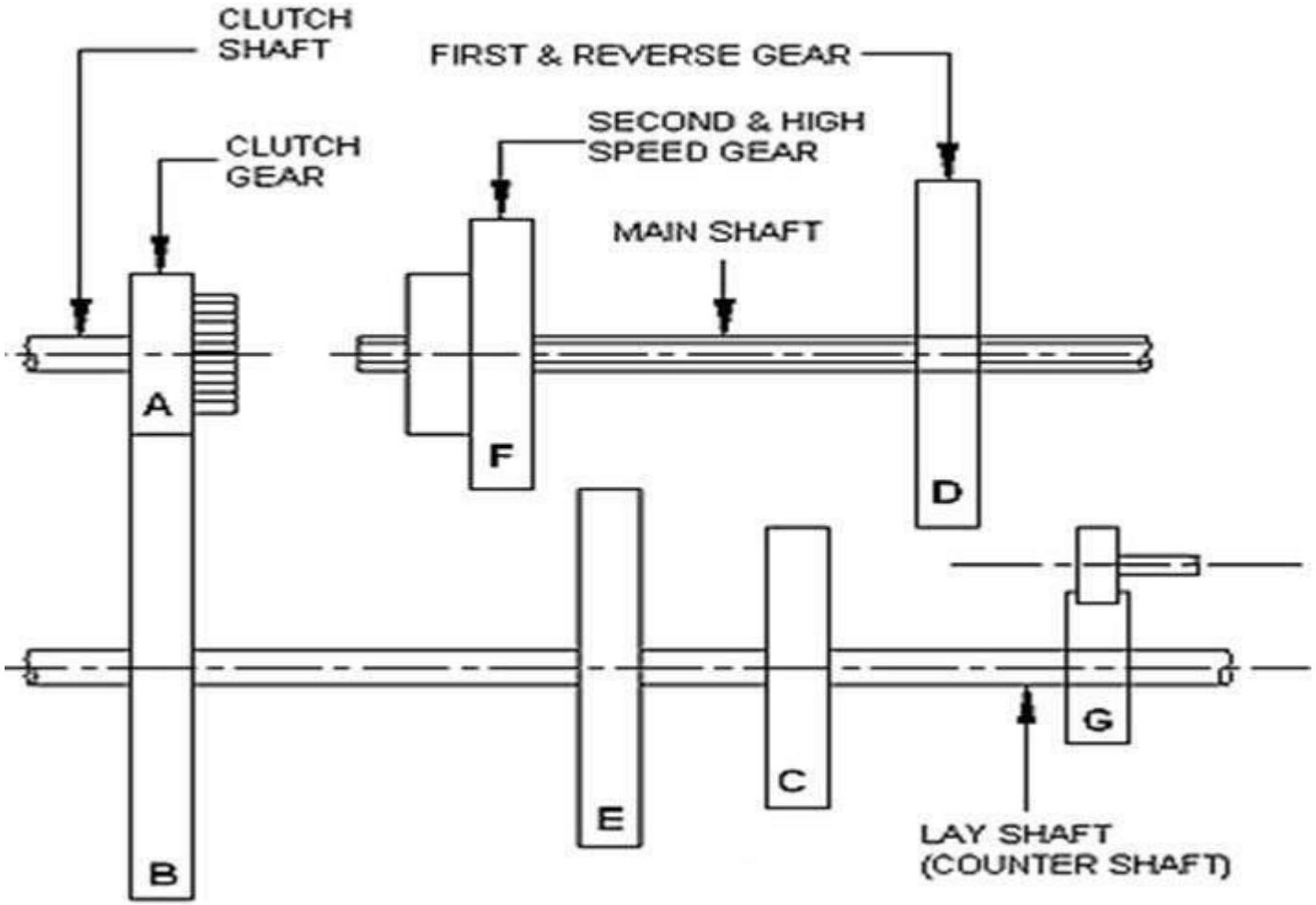
Sliding Mess Gear Box

- It is the simplest and oldest type of gear box.
- The clutch gear is rigidly fixed to the clutch shaft.
- The clutch gear always remains connected to the drive gear of countershaft.
- The other lay shaft gears are also rigidly fixed with it.
- Two gears are mounted on the main shaft and can be sliding by shifter yoke when shifter is operated.
- One gear is second speed gear and the other is the first and reverse speed gears. All gears used are spur gears.
- A reverse idler gear is mounted on another shaft and always remains connected to reverse gear of counter shaft.
- Spur gears are used in sliding mess gear box.

Sliding Mess Gear Box

- FIRST GEAR : By operating gearshift lever, the larger gear on main shaft is made to slide and mesh with first gear of countershaft. The main shaft turns in the same direction as clutch shaft in the ratio of 3:1.
- SECOND GEAR : By operating gear shaft lever, the smaller gear on the main shaft is made to slide and mesh with second gear of counter shaft. A gear reduction of approximately 2:1 is obtained.
- TOP GEAR : By operating gearshift lever, the combined second speed gear and top speed gear is forced a:dally against clutch shaft sear. External teeth on clutch gear mesh with internal teeth on top gear and the gear ratio is 1:1.
- REVERSE GEAR: By operating gearshift lever, the larger gear of main shaft is meshed with reverse idler gear. The reverse idler gear is always on the mesh with counter shaft reverse gear. Interposing the idler gear. between reverse and main shaft gear. the main shaft turns in a direction opposite to clutch shaft.
- NEUTRAL GEAR: When engine is running and the clutch is engaged. clutch shaft gear drives the drive gear of the lay shaft and thus lay shaft also rotates. But the main shaft remains stationary as no gears in main shaft are engaged with lay shaft gears.

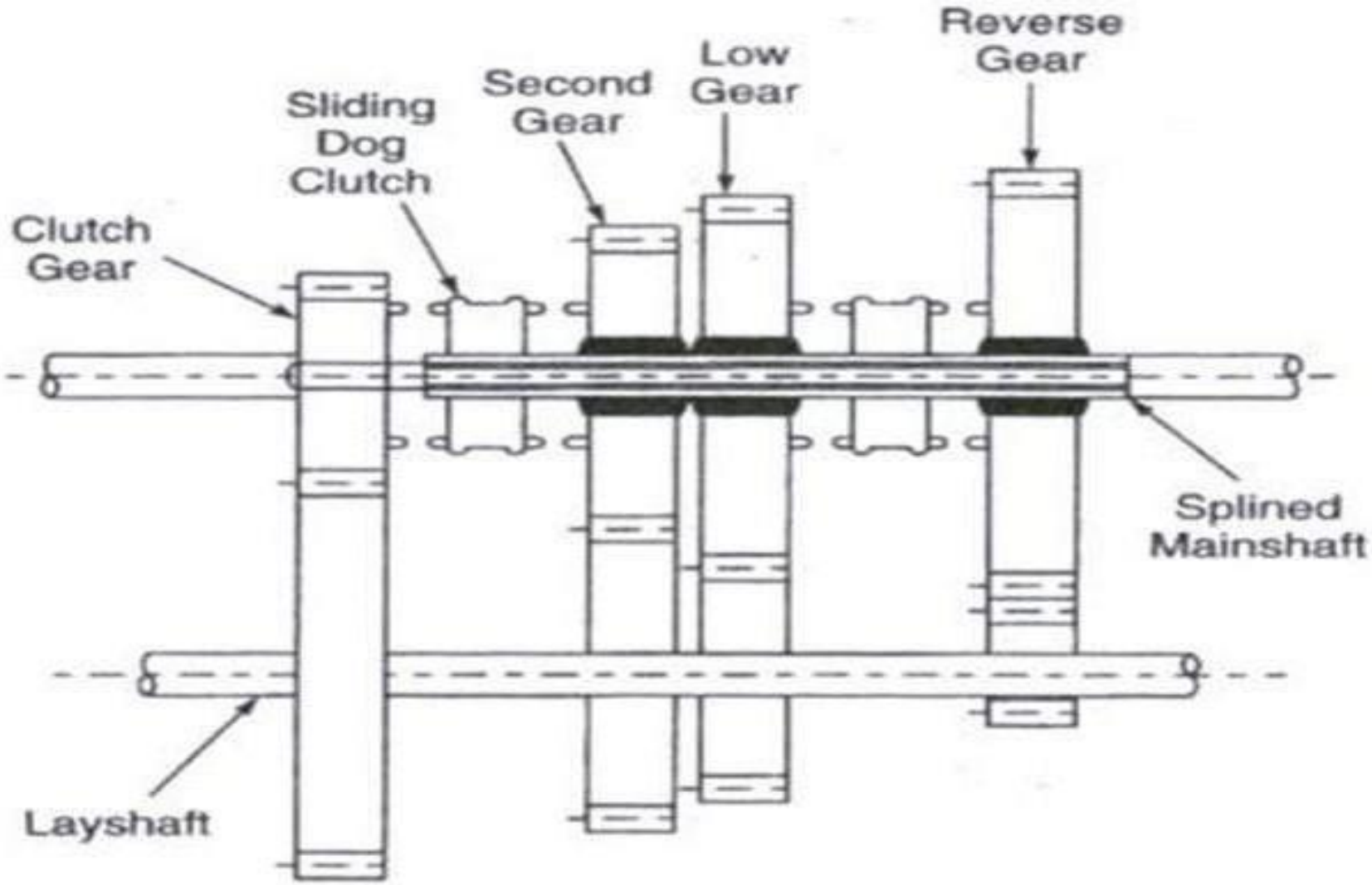
Sliding Mess Gear Box



Constant Mess Gear Box

- In this type of gear box, all the gears are in constant mesh with the corresponding gears on the lay shaft. The gears on the main shaft which is splined are free (Fig). The dog clutches are provided which are free to slide on the main shaft. The gears on the lay shaft are, however, fixed. When the left dog clutch is slid to the left by means of the selector mechanism, its teeth are engaged with those on the clutch gear and we get (the direct gear. The same dog clutch, however, when slid to right makes contact with the second gear and second gear is obtained. Similarly movement of the right dog clutch to the left results in low gear and towards right in reverse gear.
- Helical gears are used in this type of gear box.

Constant Mess Gear Box



Constant Mess Gear Box

- Advantage:

➢ In constant mess type of gear box, because all the gears are in constant mesh, they are safe from being damaged & unpleasant grinding sound does not occur while engaging & disengaging.

Double Declutching

- In the constant mesh box, for the smooth engagement of the dog clutches it is necessary that the speed of main shaft gear and the sliding dog must be equal.
- Therefore to obtain lower gear, the speed of the clutch shaft, lay shaft and main shaft gear must be increased. This is done by double declutching.
- The procedure for double declutching is as given below:

➢ The clutch is disengaged and the gear is brought to neutral.

➢ Then the clutch is engaged and accelerator pedal pressed to increase the speed of the main shaft gears.

➢ After this the clutch is again disengaged and the gear moved to the required lower gear and the clutch is again engaged.

➢ As the clutch is disengaged twice in this process, it is called double declutching.

Synchromesh Gear Box

- This type of gear box is similar to the constant mesh type in that all the gears on the main shaft are in constant mesh with the corresponding gears on the lay shaft. The gears on the lay shaft are fixed to it while those on the main shaft are free to rotate on the same.
- Its working is also similar to the constant mesh type, but in the former there is one definite improvement over the latter. This is the provision of synchromesh device which avoids the necessity of double declutching. The parts which ultimately are to be engaged are first brought into frictional contact which equalizes their speed, after which these may be engaged smoothly.
- Synchromesh devices are fitted only on the high gears and on the low and reverse gears ordinary dog clutches are only provided. This is done to reduce the cost.

Synchromesh Gear Box

- An automatic arrangement for matching the speeds of engaging dogs is called synchromeshing. The gear box employing such an arrangement is termed as synchromesh gear box. The synchronizing between engaging dog & appropriate gear is achieved by a synchronizing assembly called synchronizer.
- The construction & working principle of a typical synchronizer is shown in fig 5.7. it consist of mainly three parts:

(i) A ring having internal teeth

(ii) Synchromesh cones, male C & female D

(iii) Toothed dogs A & B

- The ring is normally held in place by spring loaded balls. It rotates with the output shaft & also be slided along the splines cut on the shaft.
- Figure 5.7 a shows disengaged position. Neither the male synchronizer cone C mesh with its female one D, nor the male toothed dog A overrides the female toothed dog B.
- the input shaft, layshaft & gears are running free.

Synchromesh Gear Box

- Now when the selector is moved in the direction shown in fig 5.7 b, the synchronizer cone C & D comes in to contact & the friction between them either speed up or slows down the gear E w.r.t the out put shaft.
- A further movement to the selector causes to the dog A & B to override by overcoming spring loaded balls, & thus the gear E is locked to the output shaft, we call it a situation of gear engagement.

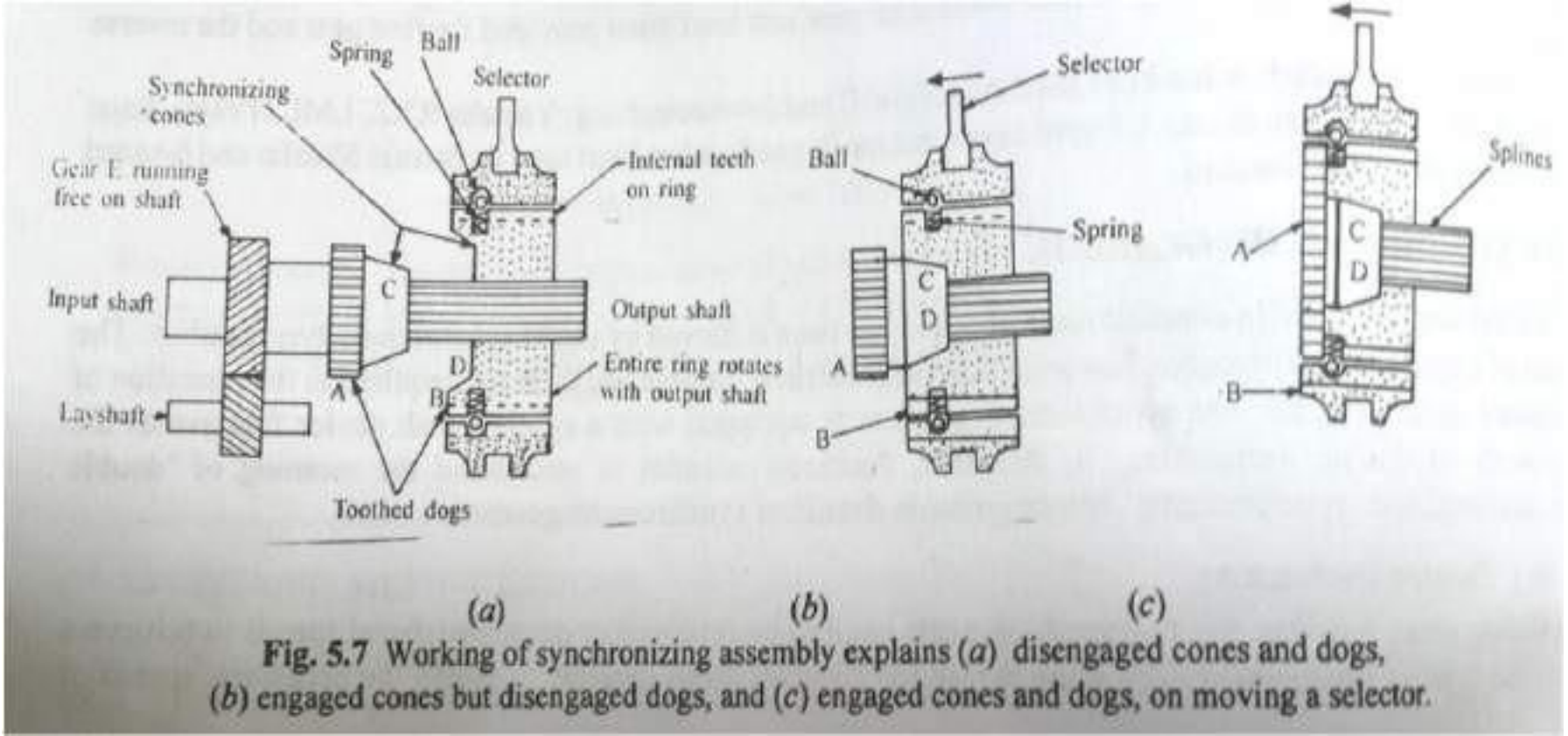


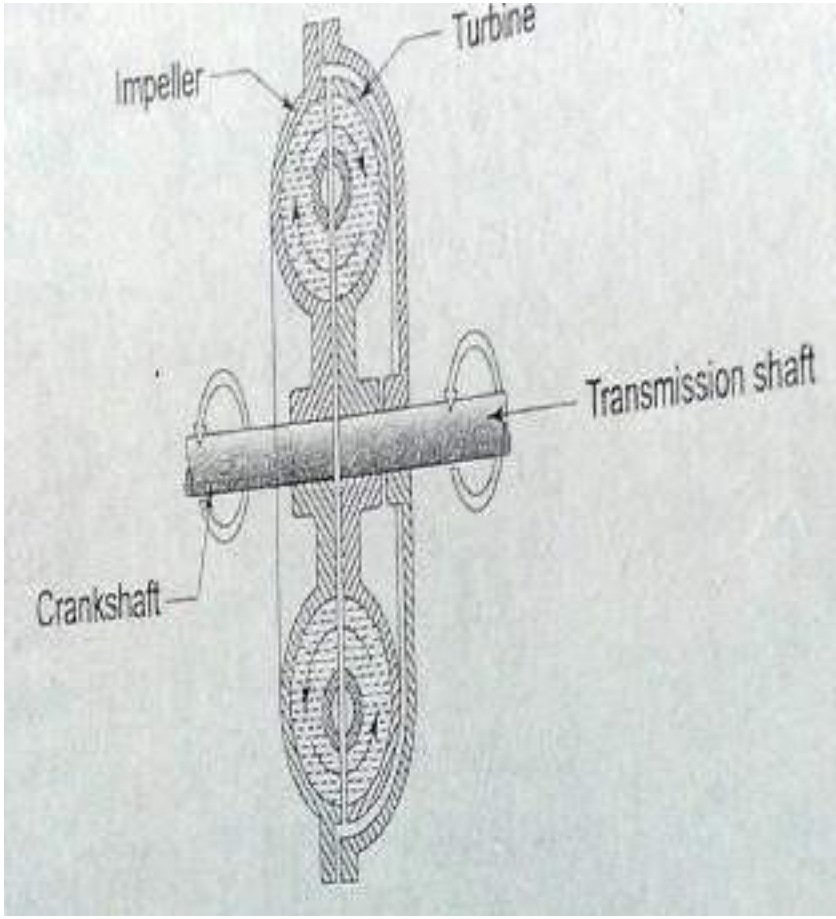
Fig. 5.7 Working of synchronizing assembly explains (*a*) disengaged cones and dogs, (*b*) engaged cones but disengaged dogs, and (*c*) engaged cones and dogs, on moving a selector.

Fluid flywheel

- Fluid flywheel or hydraulic coupling or fluid coupling as it is frequently called has been used in cars employing automatic transmission.
- It consist of two members, the driving and driven . The driving member is attached to the engine flywheel and the driven member to the transmission shaft. The two members do not have any direct contact with each other. The two rotors are always filled with fluid of suitable viscosity.

Fluid flywheel

- Working: there are two cups as shown in figure. One cup called impeller is fitted with the crankshaft. Another cup called turbine is fitted with the transmission shaft. There is oil in the coupling.
- When the crankshaft rotates the impeller also rotates. The centrifugal force acts on the oil between the vanes of the impeller due to which this oil is thrown into turbine. As a result of this, the turbine is forced to rotate. Thus the engine power is transmitted from the crankshaft to the transmission shaft.



Fluid flywheel

- Advantages:

(i) No wear on moving parts.

(ii) No adjustment is necessary.

(iii) Car can stop in gear and move off also by pressing accelerator pedal only.

(iv) Simple design.

(v) No maintenance necessary except oil level.

(vi) No skill required for operating it.

- Disadvantages:

(i) The fluid coupling is generally used with epicyclic gear box only. It cannot be used with the ordinary crash type gear box due to difficulty while changing gears.

Torque converter

Role of the torque converter:

- Multiplies torque generated by the engine.
- Serves as an automatic clutch which transmits engine torque to the transmission.
- Absorbs torsional vibration of the engine and drivetrain.
- Smoothes out engine rotation.
- Drives the oil pump of the hydraulic control system.

The torque converter is filled with automatic transmission fluid, and transmits the engine torque to the transmission. The torque converter can either multiply the torque generated by the engine or function as a fluid coupling.

Torque Converter Components

The torque converter's three major components are; the pump impeller, turbine runner and the stator. The pump impeller is frequently referred to as simply the impeller and the turbine runner is referred to as the turbine.

Pump Impeller

The impeller is integrated with the torque converter case, and many curved vanes that are radially mounted inside. A guide ring is installed on the inner edges of the vanes to provide a path for smooth fluid flow.

When the impeller is driven by the engine crankshaft, the fluid in the impeller rotates with it. When the impeller speed increases, centrifugal force causes the fluid to flow outward toward the turbine.

Turbine Runner

The turbine is located inside the converter case but is not connected to it. The input shaft of the transmission is attached by splines to the turbine hub when the converter is mounted to the transmission. Many cupped vanes are attached to the turbine. The curvature of the vanes is opposite from that of the impeller vanes. Therefore when the fluid is thrust from the impeller, it is caught in the cupped vanes of the turbine and torque is transferred to the transmission input shaft, turning it in the same direction as the engine crankshaft.

Stator

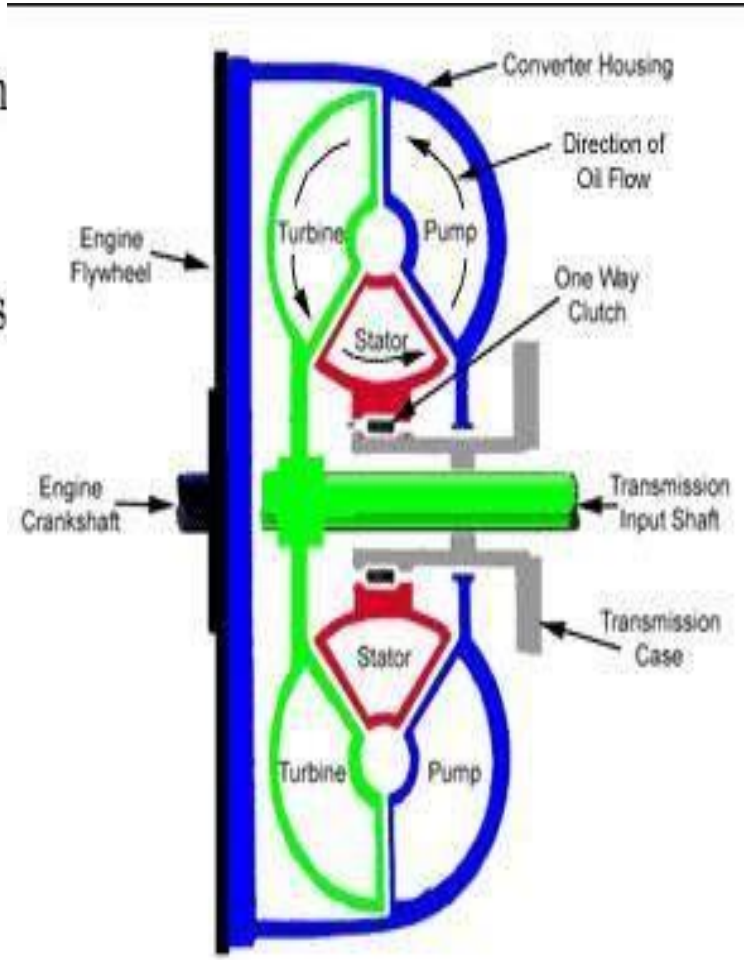
The stator is located between the impeller and the turbine. It is mounted on the stator reaction shaft which is fixed to the transmission case. The vanes of the stator catch the fluid as it leaves the turbine runner and redirects it so that it strikes the back of the vanes of the impeller, giving the impeller an added boost or torque. The benefit of this added torque can be as great as 30% to 50%.

The one-way clutch allows the stator to rotate in the same direction as the engine crankshaft. However, if the stator attempts to rotate in the opposite direction, the one-way clutch locks the stator to prevent it from rotating. Therefore the stator is rotated or locked depending on the direction from which the fluid strikes against the vanes.

Torque converter working operation

When the impeller is driven by the engine crankshaft, the fluid in the impeller rotates in the same direction. When the impeller speed increases, centrifugal force causes the fluid to flow outward from the center of the impeller and flows along the vane surfaces of the impeller. As the impeller speed rises further, the fluid is forced out away from the impeller toward the turbine. The fluid strikes the vanes of the turbine causing the turbine to begin rotating in the same direction as the impeller.

After the fluid dissipates its energy against the vanes of the turbine, it flows inward along the vanes of the turbine. When it reaches the interior of the turbine, the turbine's curved inner surface directs the fluid at the vanes of the stator, and the cycle begins again.

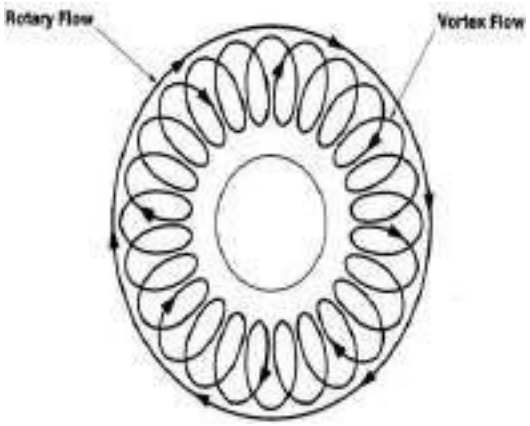


➢ Torque converter fluid flow:

- Following types of flow developed during operation of converter:

a. Vortex flow occurs while vehicle is accelerating (impeller turning faster than turbine).

b. Rotary flow occurs while vehicle is crusing (impeller and turbine at all most same speed).



➢ Phases of operation:

a. Torque multiplication:
- Relatively low impeller (engine) RPM's
- Stator is locked into place by its one-way clutch
-Vortex fluid flow within the converter

b. Coupling phase:
- Occurs at normal driving conditions
- No torque multiplication
- Stator is freewheeling
- Turbine is spinning at approx 90% of impeller speed
- Rotary flow within the converter

Overdrives

In the top gear position, it is direct drive between the clutch shaft and the main shaft of the gear box. The gear ratio is 1 : 1 in this position. Through this transmission, there is neither gear reduction nor gear increase.

Sometimes, at high speeds, the main shaft of the gear box should necessarily turn faster than the clutch shaft. In this case the overdrive gear unit plays an important part.

The transmission is in overdrive, when the main shaft of the gear box is turning faster than the clutch shaft.

The overdrive is fitted to the rear of the gear box between the gear box and the propeller shaft. It is described below.

Construction

There are two shafts in the overdrive, namely the input and the output shaft. The main shaft of the gear box becomes the input shaft of the overdrive. The output shaft of the overdrive is connected to the propeller shaft.

There is an epicyclic train in which the sun gear is free to rotate on the input shaft. The carrier can move on splines on the input shaft. A free wheel clutch is also attached on these splines. The ring is connected to the output shaft.

Operation

When the sun gear is locked with the casing, it becomes stationary. In this situation, overdrive is engaged, thus increasing the speed of the output shaft.

When the sun gear is locked to the carrier, solid drive through the gear train is achieved. That is, normal direct drive is obtained. The same effect happens when the sun gear is locked to the ring.

Overdrives

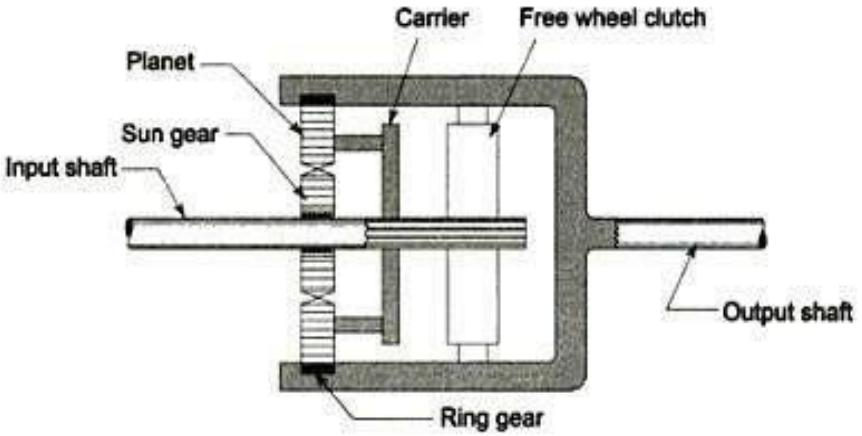
Advantages

The overdrive permits an engine at lower speed to maintain the car at high speed. When the car is moving at a steady speed, it does not require as much power to keep it moving.

As a result, the engine can run slower, produce power less than what is required, and still maintain the same car speed. Thus the fuel used by the car is saved and wear on the engine and accessories is reduced.

For example, when a car without the overdrive runs at 60 km per hour, assume that the engine crankshaft revolves at 1900 per minute. Suppose the same car runs with overdrive at 60 km per hour. Now the crankshaft of the engine will revolve only at 1300 per minute. This indicates that due to the overdrive, the revolution of the engine crankshaft is reduced from 1900 to 1300 per minute for the same speed. This saves a lot of fuel.

Another example is that of a typical overdrive gear box which can maintain a car at a speed of 89 km per hour while allowing the engine to turn at the equivalent of only 71 km per hour. Thus the consumption of fuel by the car is reduced.



Overdrive

- A **semi-automatic transmission** (SAT) (also known as a **clutchless manual transmission**, **automated manual transmission, flappy-paddle gearbox**, or **paddle-shift gearbox**) is an automobile transmission that does not change gears automatically, but rather facilitates manual gear changes by dispensing with the need to press a clutch pedal at the same time as changing gears. It uses electronic sensors, pneumatics, processors and actuators to execute gear shifts on the command of the driver or by a computer. This removes the need for a clutch pedal which the driver otherwise needs to depress before making a gear change, since the clutch itself is actuated by electronic equipment which can synchronise the timing and torque required to make quick, smooth gear shifts.

- A semi-automatic transmission is a very advanced system,

which still uses a clutch to perform the gear shift instead of a torque converter. Unlike the manual transmission, the computer does all of the clutch disengaging, gear shifting, and clutch engaging. This not only makes the gear shifting faster than manual transmission, but also prevents the vehicle from stalling when the car is stationary.

- **The two most common semi-automatic transmissions are direct shift transmission (aka dual-clutch transmission) and electrohydraulic manual transmission (aka sequential transmission)**

Propeller shaft

- Function of propeller shaft:- This is a shaft which transmits the drive from the transmission system (gear box) to the rear axle through differential.

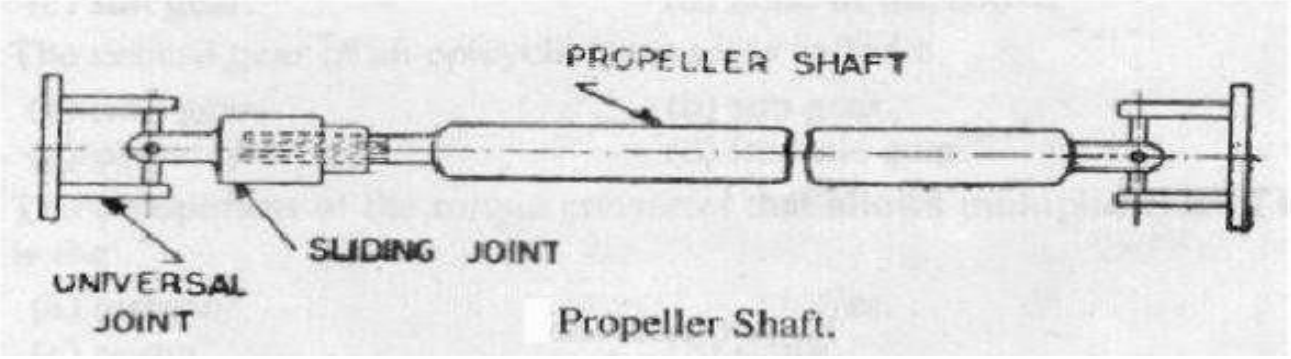
1. Transmit the power from gear box top final dive.
2. To compensate the change in length.
3. Transmit motion at an angle which is varying frequently.

- The rotary motion of the transmission main shaft is carried out through the propeller shaft to the differential, thus causing the rear wheels to rotate.
- Propeller shaft is used in front engine rare wheel drive vehicle to connect gear box & differential.
- Propeller shaft is manufactured in thin walled steel tube.

Propeller shaft

- The propeller shaft has following three components:

1. Shaft: it has to withstand mainly torsional loads. Therefore, it is usually made of tubular cross-section. At high speeds, whirling should be avoided. For this reason, this shaft has to be well balanced. Shafts are made of steel, aluminum or composite material
2. Universal joint: one or more universal joints are used to permit angle change.
3. Slip joint: depending upon the type of the drive, one slip joint may be employed in the shaft. This helps to adjust the length of the propeller shaft, according to the rear axel movements.

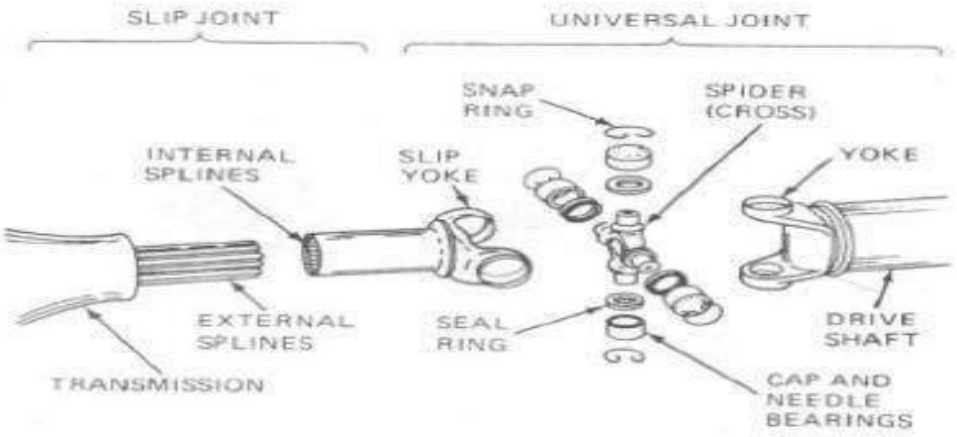


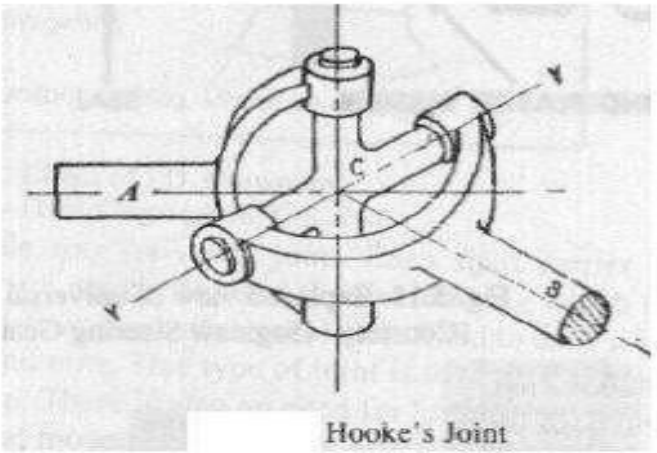
Universal joint

- The purpose of universal joints is to transmit power (torque) even at varied angles of the transmission system (propeller shaft).
- Power is transmitted from the gear box to the differential via the propeller shaft. Gear box is connected to one end of the propeller shaft by means of the universal joint. The differential is connected to the other end of the propeller shaft by means of another universal joint.
- The most common type of universal joint is Hook's Joint.

Cross type or spider & two yoke (Hook's Joint)

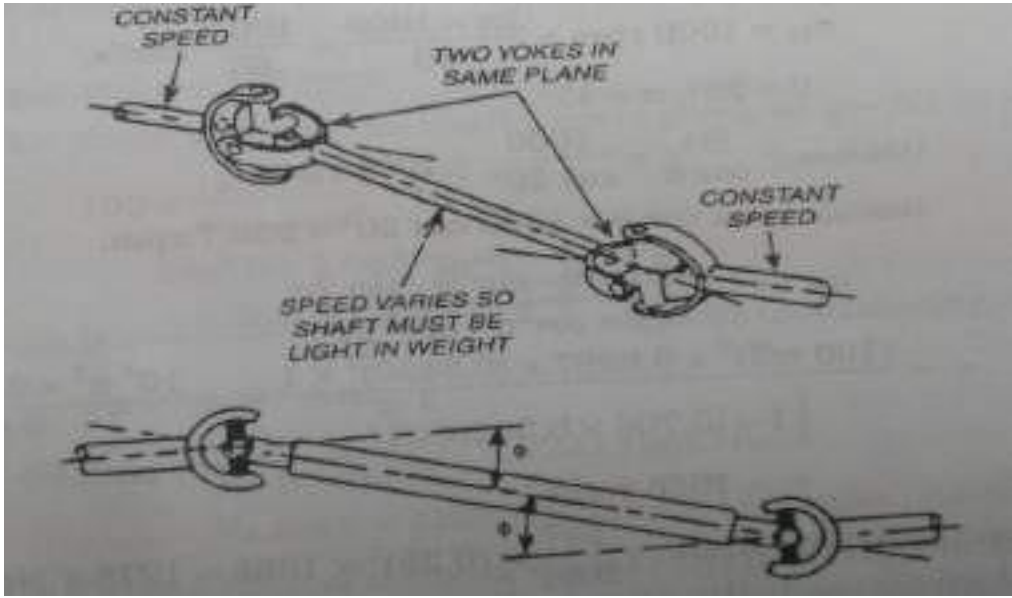
- A single universal joint is shown in fig, there is a driving yoke on one side which is connected to the main shaft of the gear box & the driven yoke is connected to the propeller shaft. These two yokes are connected by means of a crossed spider. When the driving shaft rotates, the driven shaft also rotates. At the same time the universal joint permits angular motion. This propeller haft can rotate at any angle. Thus power is transmitted from the gear box to the propeller shaft at any particular angle.
- Universal joints have one common defect i.e. the speed of the driven shaft does not remain constant. Depending upon the angle of inclination of the shafts, driven shaft speed undergoes cyclic variation as shown in fig.





Constant velocity universal joint

- This type of joints permit movement of both driving & driven shaft at constant velocity.
- One method to achieve a uniform driven shaft speed is by using two such joints as shown in fig.
- The intermediate shaft is so arrange that it makes equal angles with first and third shifts.
- The variation caused by one joint is then cancelled out by the second joint.
- however, this will be valid only when the angles on both joints are exactly equal, which is not always the case in practice.



Constant velocity joint

1. Constant velocity joints are used where the front axle are being driven, regulation of rotation and transmission of torque at large indication are vital.
2. In these vehicles the inclination between the shafts may assume a large varying (40°).
3. The speed of shaft connected by these joints is absolutely equal.

Final drive

- In most automobile vehicles the final driver is embodied in rear axle.
- But in various popular vehicles with front wheel drive and a few special purpose vehicles with four wheel drive, it becomes necessary to consider final drives as units dependent of their positions.

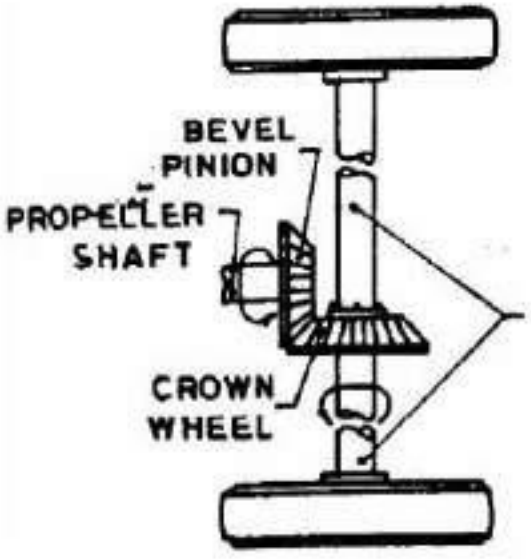
➢ FUNCTIONS OF FINAL DRIVE: In a motor vehicle the final drive has two purposes.

1) To provide a permanent speed reduction. For motor cars the reduction is usually about 4:1 and 10:1 in heavy vehicle.
2) To turn the drive through 90^{o} so that the torque may be transmitted from propeller shaft to the rear axle.

Construction of final drive

1) The final drive consist of a bevel pinion and crown wheel (ring gear)as shown in the figure.
2) The bevel pinion is mounted on the shaft
3) From the crown wheel the drive goes to the rear axle through the diffrential.
4) There are three types of the final drive gearing:

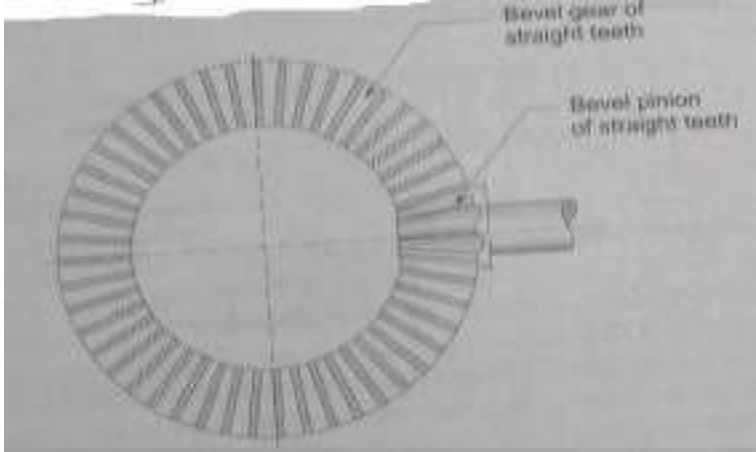
a. Straight Bevel gears
b. Sprial Bevel Gears
c. Hypoid Gears

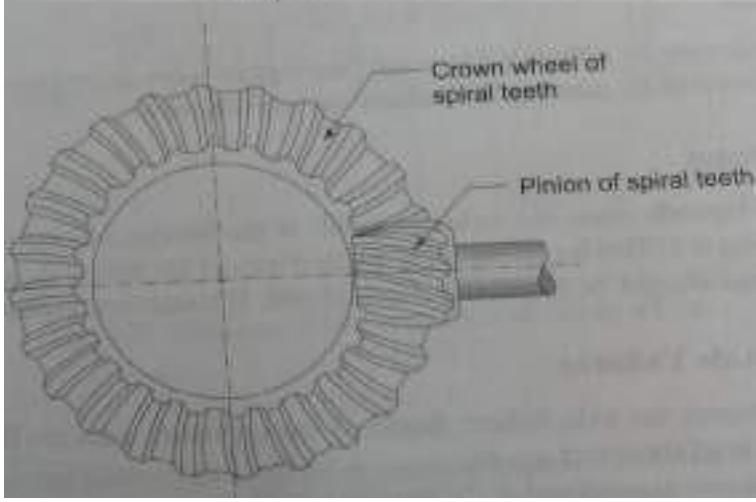


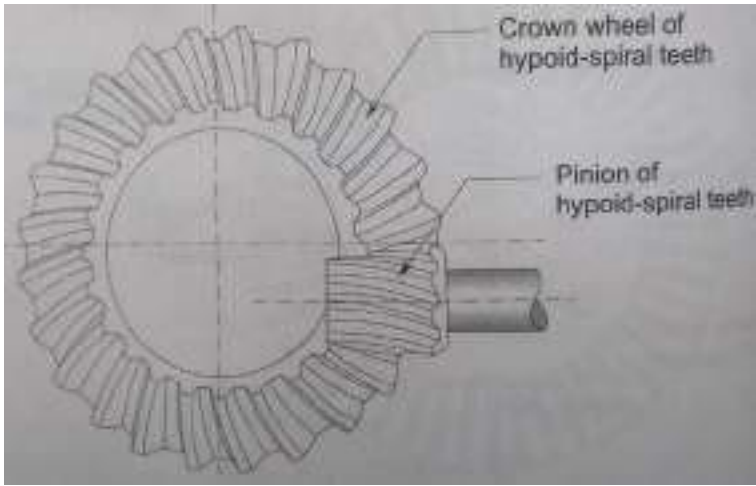
- Straight Bevel gears: this is the arrangement made in the older models. In this, the teeth of the crown wheel are straight. A bevel pinion of the propeller shaft is in mesh with the bevel gear of the crown wheel.

- Spiral bevel gear: in this the teeth of the crown wheel are in the form of a spiral gear. The pinion of the propeller shaft also has teeth in the same form. No sound is developed when these teeth mesh & the meshing is also very smooth. These are the advantages of this unit.

- Hypoid spiral gear: this is a form of bevel pinion & crown wheel drive. The axis of the pinion shaft is below the centre of the crown wheel. In this arrangement too the running is noiseless.







Construction of final drive

1) Final drive is the last stage in transferring power from engine to wheels.
2) It reduces the speed of the propeller shaft (drive shaft) to that of wheels.
3) It also turns the drive of the propeller shaft by an angle of 90^{o} to drive the wheels.
4) The propeller shaft has a small bevel pinion which meshes with crown wheel. The crown wheel gives rotary motion to rear axles.
5) The size of crown wheel in bigger than that of bevel pinion, therefore, the speed of rear axles (or crown wheel) in lower than the speed of pinion.
6) Final drive is of two types, i.e. chain type and gear type.
7) For final reduction in speed two types of gears can be used.
8) One of them may be use of bevel gears and another may be worm and worm wheel.
9) Worm and worm wheel combination provides large reduction without employing larger gears. It is strong also.

Differential

1) When a vehicle travels in a straight-line, the two rear wheels turn on road exactly at same speed & there is no relative movement between the rear wheels.
2) But when vehicle takes a turn, the outer wheel turns on a longer radius than inner wheel. The outer wheel turns faster than inner wheel i.e. there is relative movement between two rear wheels.
3) If the two rear wheels are rigidly fixed to a solid rear axle, the inner wheel will slip, which will cause rapid tire wear, steering difficulties & poor road holding.
4) Therefore there must Le some mechanism in the rear axle which should reduce the speed of inner wheels & increase the speed of outer wheels while taking turns.
5) It should be at the same time keep the speeds of all the wheels same when going straight ahead. Such a device which serves the above function is called as differential.

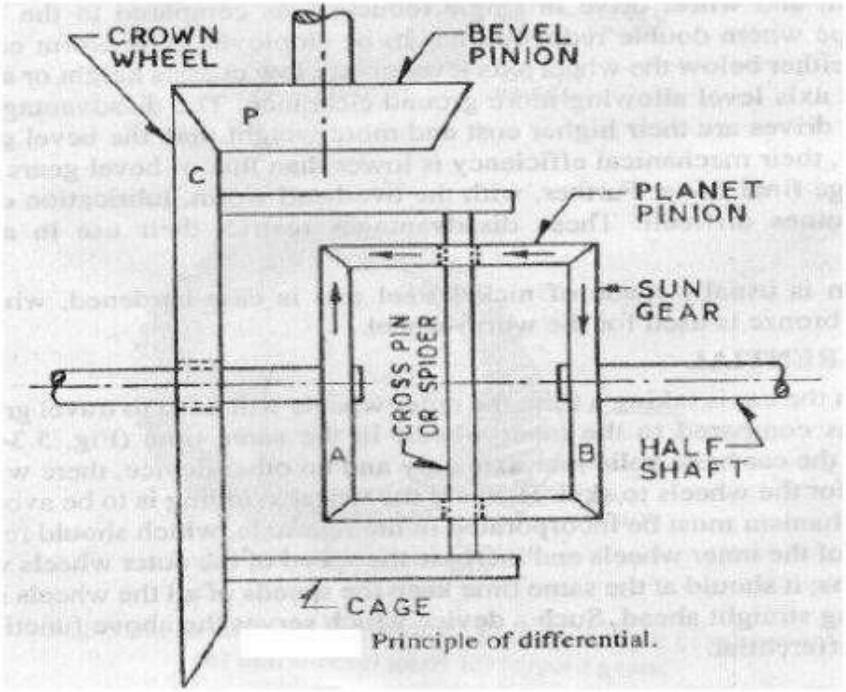
Differential

- To understand the principle on which differential works consider figure:

1. To the crown wheel of the final drive is attached a cage, which carries a cross-pin where two planet pinions are employed.
2. Two sun gears mesh with the two planet pinions. Axle half shafts are splined to each of these sun gears.
3. When the vehicle is going straight, the cage & inner gears rotate as a single unit & two half shafts revolve at same speed. In this situation, there is no relative movement among the various differential gears.
4. To understand what happens when the vehicle is taking turn, assume that the cage is stationary. Then turning any one sun gear will cause other to rotate in the opposite direction.
5. This means that if the left sun gear rotates "n" times in a particular time. the right gear will also rotate "n" in the same period. but of course in opposite direction.

Differential

6. Thus for example, consider a vehicle with wheel speed "N" r.p.m. going straight. When it takes turn towards, there will be resistance to the motion of right wheel & as a result differential action: if the right wheel rotates back at "n" rpm, then left wheel will rotate forwards at "n' rpm. This will give resultant speed of left wheel as (N+n) and that of right wheel as (N-n) rpm.



Principle of differential.

Non slip differential

- Conventional type differential described delivers same torque to each rear wheel. If any of the wheels slips due to any reason the wheel does not rotate and vehicle does not move.

- Non-slip or limited slip differential or self locking type differential overcomes this drawback:

1) A self locking differential consists of two clutches, one on each side, to lock the side gears and axles to the differential cage, when the differential action is not desired.
2) The mechanism consists of four differential pinion gears mounted on two cross shafts at right angles to each other.
3) When the differential cage is driven by the rear axle gears, the turning resistance causes the cross shafts to move up the ramps and push the shafts apart.
4) This action forces the pinions on each shaft to bear against the side gear rings in order to apply the clutch which locks both axle shafts and force them to turn at the same speed.

Differential Lock

1) The torque transmitted by the bevel gear differential to each of the rear wheels remains equal even when they are rotating at different speeds.
2) Due to this reason if one wheel in on a slippery surface, mend, lose dirt or sand the wheel on the solid ground will not be driven while the other spins around idly.
3) When the differential lock is applied, the differential action is stopped and the whole torque is then applied to the wheel which is gripping on the road.

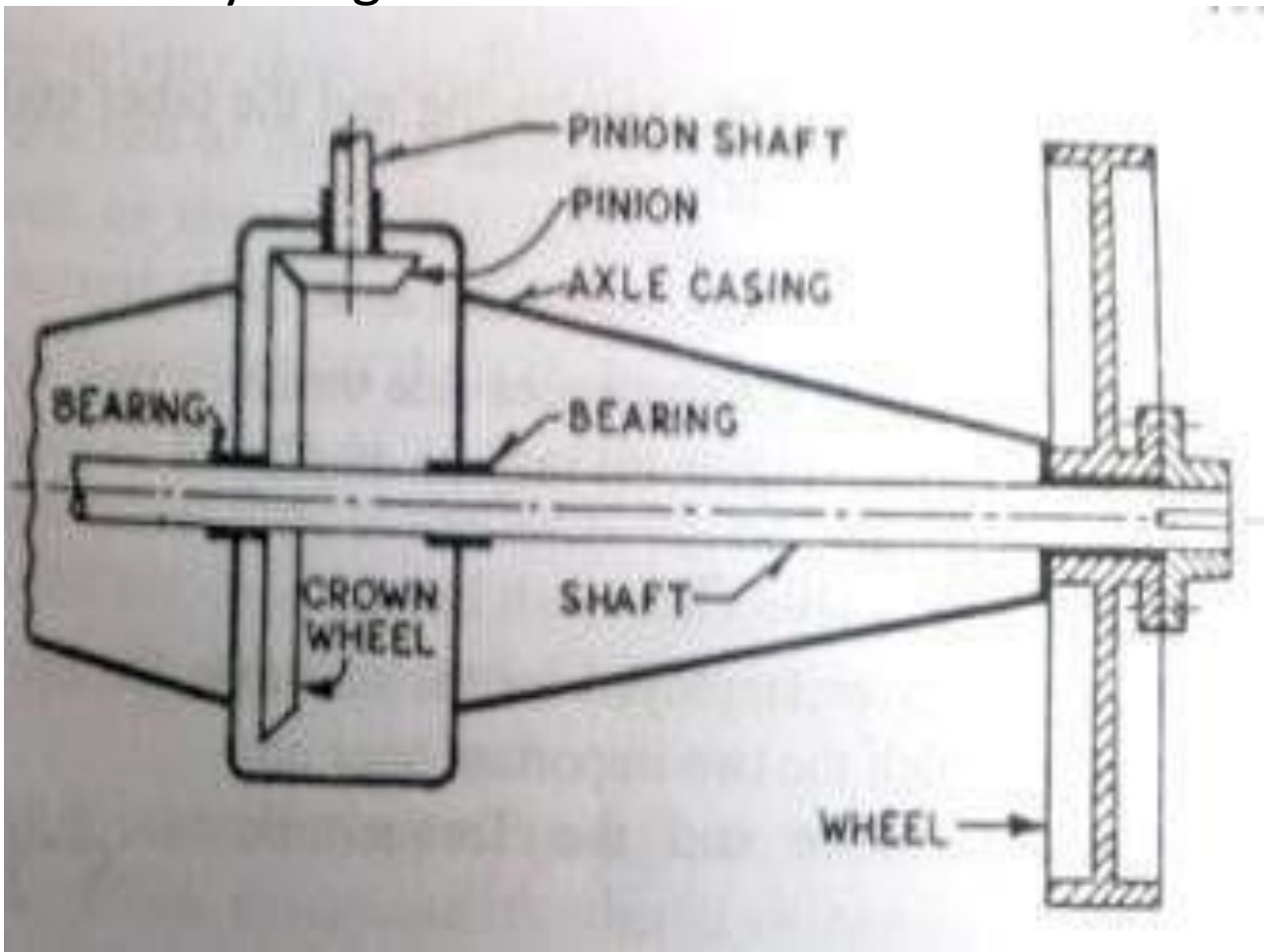
Rear axle

1. Rear axle transmits power from differential to the wheels so that vehicle may move.
2. Rear axle is not a single piece but it is in two parts which are connected by the differential.
3. Each part of rear axle is called the half shaft.
4. Outer end of the rear axle carries the wheel while inner end is connected to sun gear of the differential.
5. In vehicles which employ rear wheel drive, rear wheels are driving wheels. However, in front wheel drive vehicles, front wheels are driving wheels.
6. Rear axles and differential are completely enclosed in a housing to protect them from dust, dirt, water and any possible damage.

Rear Axel

Function of rear axel:

1. To transmit power from differential to wheels
2. To carry weight of automobile.



Rear wheel drive

- Commonly used rear wheel drive are:

1. Hotchkiss drive:
2. Torque tube drive:

Rear axel drive

1. Hostchkiss drive:

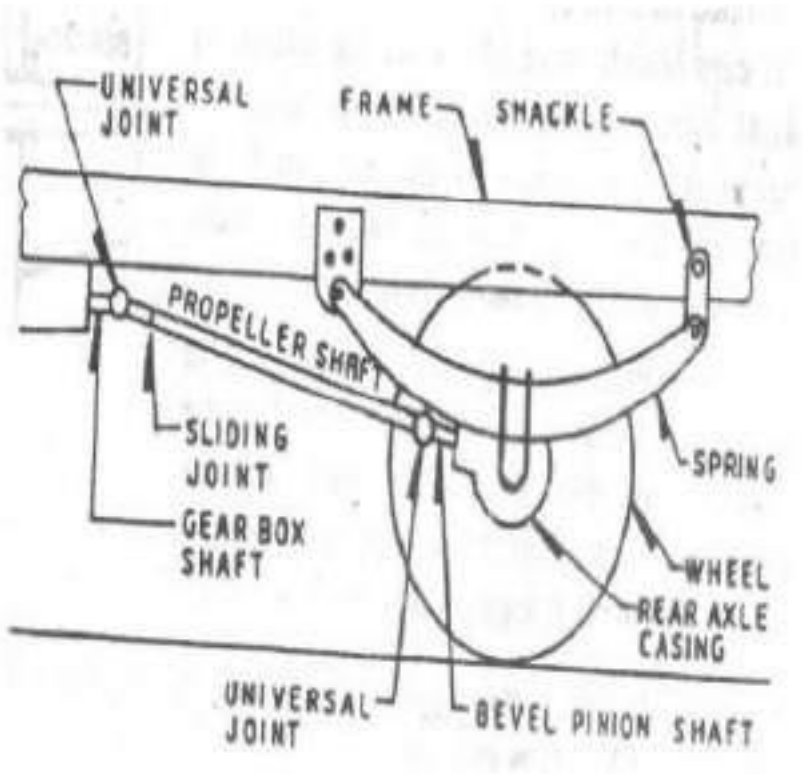
a) This is the simplest and most widely used type of rear axle drive.

b) In this case the springs besides taking weight of the body also take the torque reaction, driving thrust and side thrust.

c) The propeller shaft is provided with two universal joints also a sliding joint.

d) The springs is fixed rigidly in the middle to the rear axle.

e) The front end of the spring is fixed rigidly on the frame while the rear end is supported in the shackle.



Rear axel drive

2. Torque tube drive:

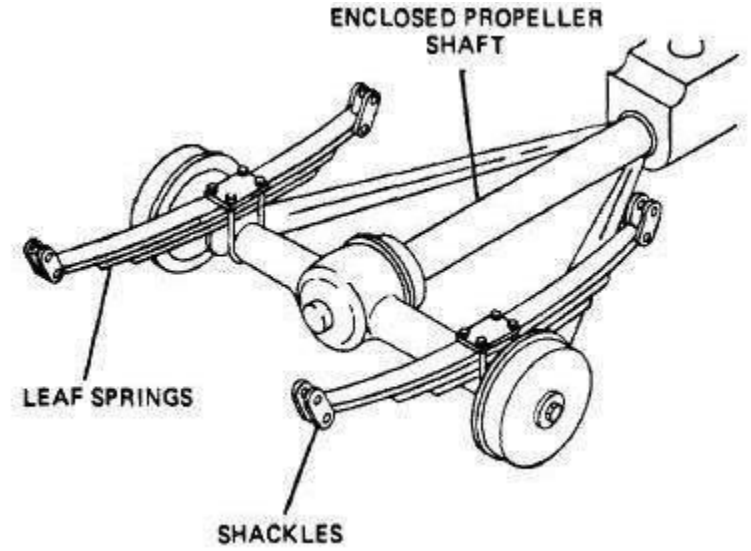
a. In this type ot drive the spring takes only the side thrust besides supporting the body weight.

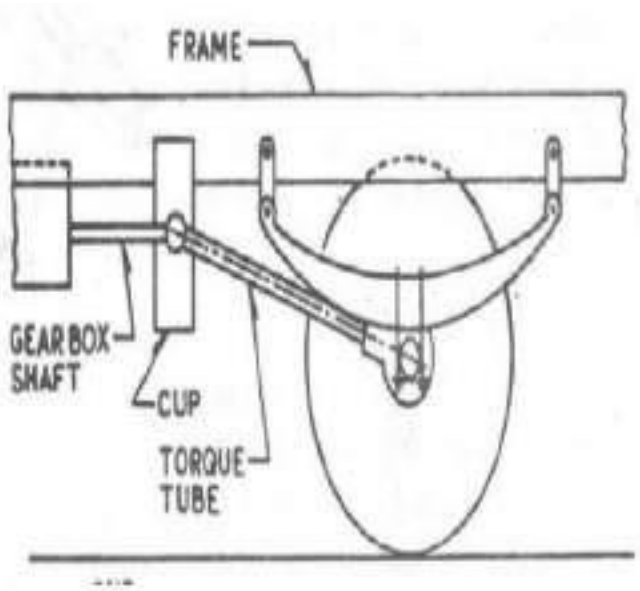
b. The torque reaction and driving thrust are taken by another member which is called torque tube.

c. One end of the torque tube is attached to the axle casing, another end which is in spherical shape fixed in the cup fixed to the frame.

d. The torque tube encloses the propeller shaft since the torque tube takes the torque reaction the centre line of the bevel pinion shaft will not shift.

e. So that no sliding joint is required and one universal joint is enough.





Rear axel shaft supporting

- **Load on Rear live axle half shaft**

The various loads on rear live axle half shaft are

a. Shaft force due to vehicle weight
b. Bending moment on accountant of the offset of vehicle load applied through spring seats and road wheels.
c. End thrust carried by side forces
d. Bending moment caused by end thrust and its reaction offered by tyres
e. Driving torque

Types of Rear Axle Support

Rear axles differ on the basis of method of supporting them and mounting of rear wheels.

On this basis, these axles can be classified into three types:

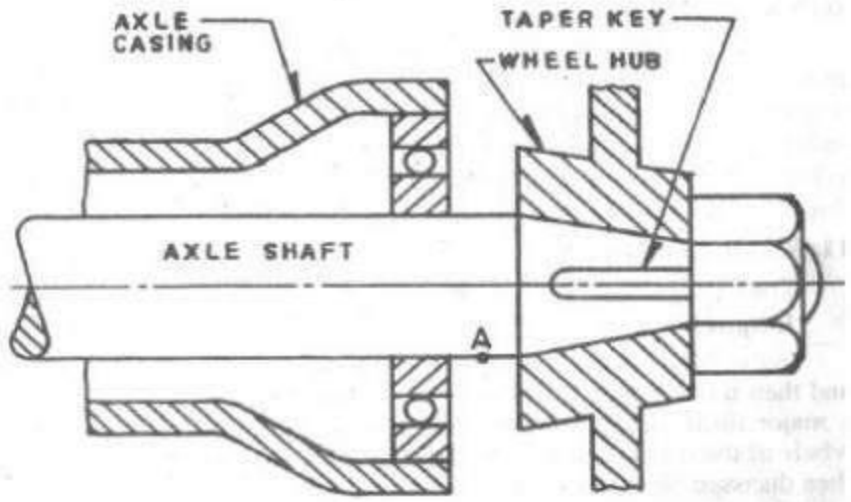
(a) Half floating axle /semi floating type

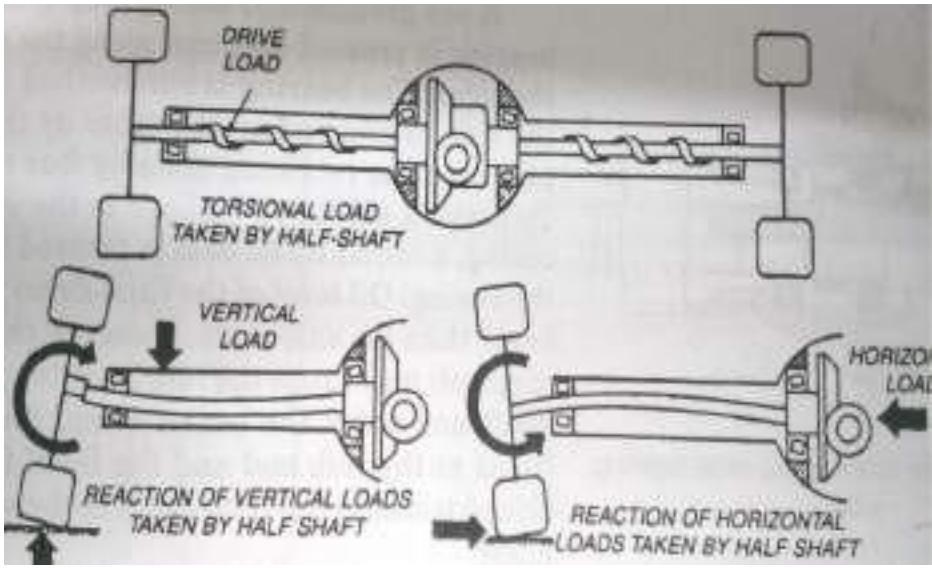
(b) Three-quarter floating axle

(c) Fully floating rear axle.

1. Semi floating type rear axel:

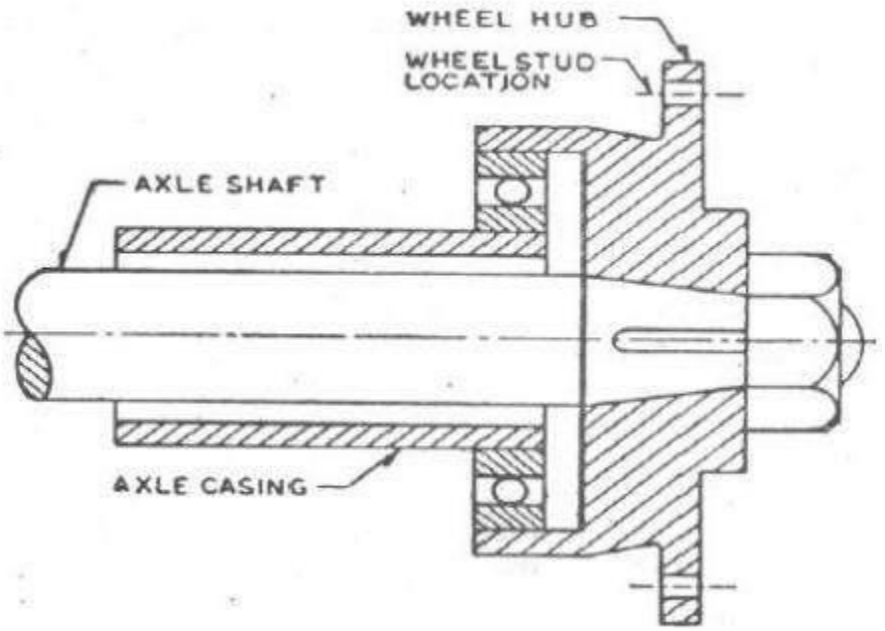
1) An axle in which the shaft has to take the entire load is called semi or non floating axle.
2) In this wheel hub is directly connected to the axle.
3) The inner end of the axle shaft is splined and is supported by the final drive unit where as outer end is supported by a single bearing inside the axle casing.
4) In this type all the loads are taken by the axle shaft.
5) The whole load acts on the shaft and shaft has a tendency to shear at the point A.
6) The semi floating axle is the simplest and cheapest but for a given torque they have to be of larger dia. for the same torque transmitted compared to the other type of rear axle supports.

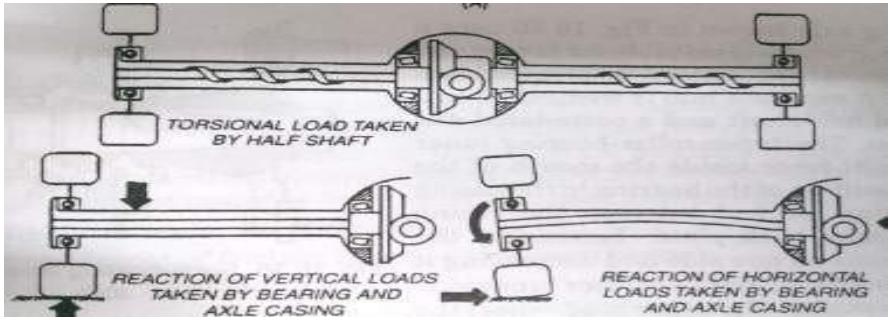




2. Three quarter floating axle:

1) This type of axle is a combination of full and semi floating bearing.
2) In this bearing is locating between the axle casing and hub axle shaft do not have to withstand any shearing or bending action due to the weight of the vehicle, which are taken up by the axle casing through the hub and bearing.
3) However it has to take the end loads and driving torque.





IGNITION SYSTEMS & FUEL INJECTION SYSTEMS

Ignition System:

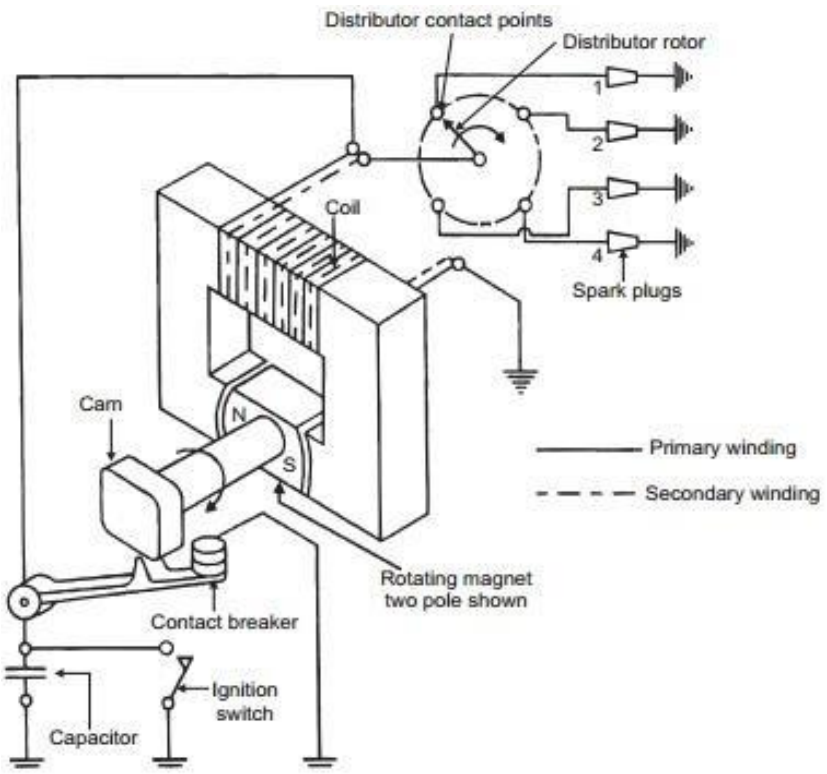
The ignition system is a system used to generate a very high voltage from the car battery and to send it to each sparkplug in turn thereby igniting the fuel-air mixture in the combustion chamber of the engine.

Types of Ignition System:

1. Magneto ignition systems
2. Battery coil ignition systems
3. Electronic ignition system

Magneto ignition systems:

This type of ignition system is mostly used in motorcycles, scooters and racing cars. The magneto Ignition system with main components is shown below:



Schematic of rotating magnet type magneto ignition systems

Magneto ignition system is a special type of ignition system with its own electric generator to provide the required necessary energy for the vehicle system. It is mounted on the engine and replaces all components of the coil ignition system except the spark plug. A magneto when rotated by the engine is capable of producing a very high voltage and doesn't need a battery as source of external energy.

The main components of an ignition coil are

Distributor, Condenser, Contact Breaker (CB) points, Ignition Coil.

There are two important types of magneto ignition system. They are 1) Rotating armature type and 2) Rotating Magnet type.

In the first type, the armature consisting of the primary and secondary windings rotate in between the poles of a stationary magnet. In the second type the magnet revolves and windings are kept stationary is shown in the above figure. A third type of magneto called the polar inductor type magneto, where both the magnet and the windings remain stationary but the voltage is generated by reversing the flux field with the help of soft iron polar projections called inductors.

Condensor:

The function of the capacitor is to reduce arcing at the contact breaker (CB) points. Also when the CB opens the magnetic field in the primary winding

begins to collapse. When the magnetic field is collapsing capacitor gets fully charged and then it starts discharging and helps in building up of voltage in secondary winding.

Contact Breaker:

It is to be noted that the Contact breaker cam and distributor rotor are mounted on the same shaft.

Distributor:

Ignition Coil:

The main advantage of the high tension magneto ignition system is the production of a very high voltage.Because of the poor starting characteristics of the magneto system invariably the battery ignition system is preferred to the magneto system in automobile engines. However, in two wheelers magneto ignition system is preferred due to light weight and less maintenance.

Battery coil ignition systems:

It is used in passenger cars and light trucks. A Battery Ignition system for four cylinder engine where the battery supplies the electrical energy. An ignition switch is used to control the battery current for starting or stopping the engine. The ignition coil transforms the battery low tension current to high tension current required to produce a spark by jumping in a spark plug. The distributor delivers the spark to the proper cylinder and incorporates the mechanical breaker, which opens and closes the primary circuit at exact times.

The various units are connected by electrical wiring. The spark plugs provide the spark in engine cylinder.

The figure shows battery ignition system for a 4-cylinder petrol engine. It mainly consists of a 6 or 12 volt battery, ammeter, ignition switch, auto-transformer (step up transformer), contact breaker, capacitor, distributor rotor, distributor contact points,

spark plugs, etc.

The ignition system is divided into 2-circuits namely the Primary Circuit and Secondary Circuit.

(i) Primary Circuit : It consists of 6 or 12 V battery, ammeter, ignition switch, primary winding it has 200-300 turns of 20 SWG (Sharps Wire Gauge) gauge wire, contact breaker, capacitor. 53

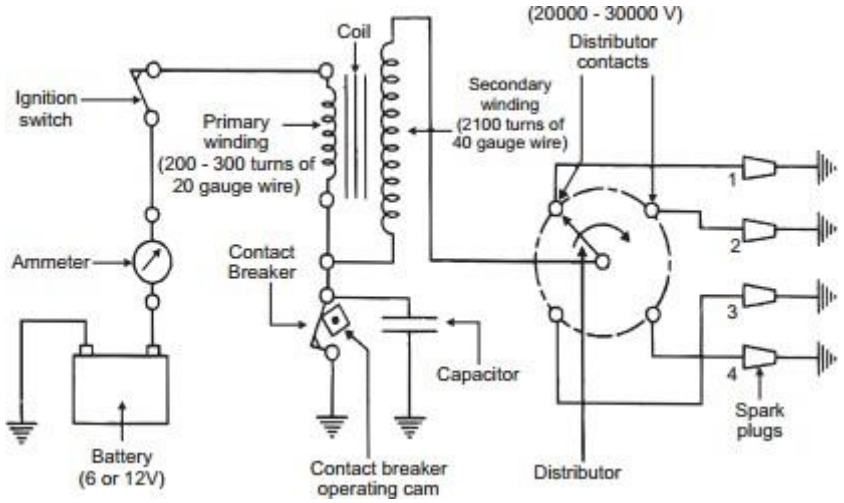
(ii) Secondary Circuit: It consists of secondary winding. Secondary Ignition Systems winding consists of about 21000 turns of 40 (S WG) gauge wire. Bottom end of which is connected to bottom end of primary and top end of secondary winding is connected to centre of distributor rotor. Distributor rotors rotate and make contacts with contact points and are connected to spark plugs which are fitted in cylinder heads.

Working:

When the ignition switch is closed and engine in cranked, as soon as the contact breaker closes, a low voltage current will flow through the primary winding. When the contact breaker opens the contact, the magnetic field begins to collapse. Because of this collapsing magnetic field, current will be induced in the secondary winding. And because of more turns of secondary, the voltage goes upto 20000-35000 volts.

This high voltage current is brought to centre of the distributor rotor. Distributor rotor rotates and supplies this high voltage current to proper stark plug depending upon the engine firing order. When the high voltage current jumps the spark plug gap, it produces the spark and the charge is ignited-combustion starts-products of combustion expand and produce power.

When compared to the magneto ignition system, the battery ignition system is more expensive but at the same time it is very highly reliable as it aids in reliable sparking..



Schematic Diagram of battery ignition systems

Electronic ignition system:

The requirement for higher mileage, reduced emissions and greater reliability has paved the way for development of the electronic ignition systems. The main advantages of the electronic ignition system are

It provides better emission control.

It provides a reasonable fuel economy. It provides

better engine performance.

Spark plug:

The spark plug consists of a porcelain insulator in which there is an insulated electrode supported by a metal shell with a grounded electrode. They have a simple purpose of supplying a fixed gap in the cylinder across which the high voltage surges from the
coil must jump after passing through the distributor. The spark plugs use ignition coil high voltage

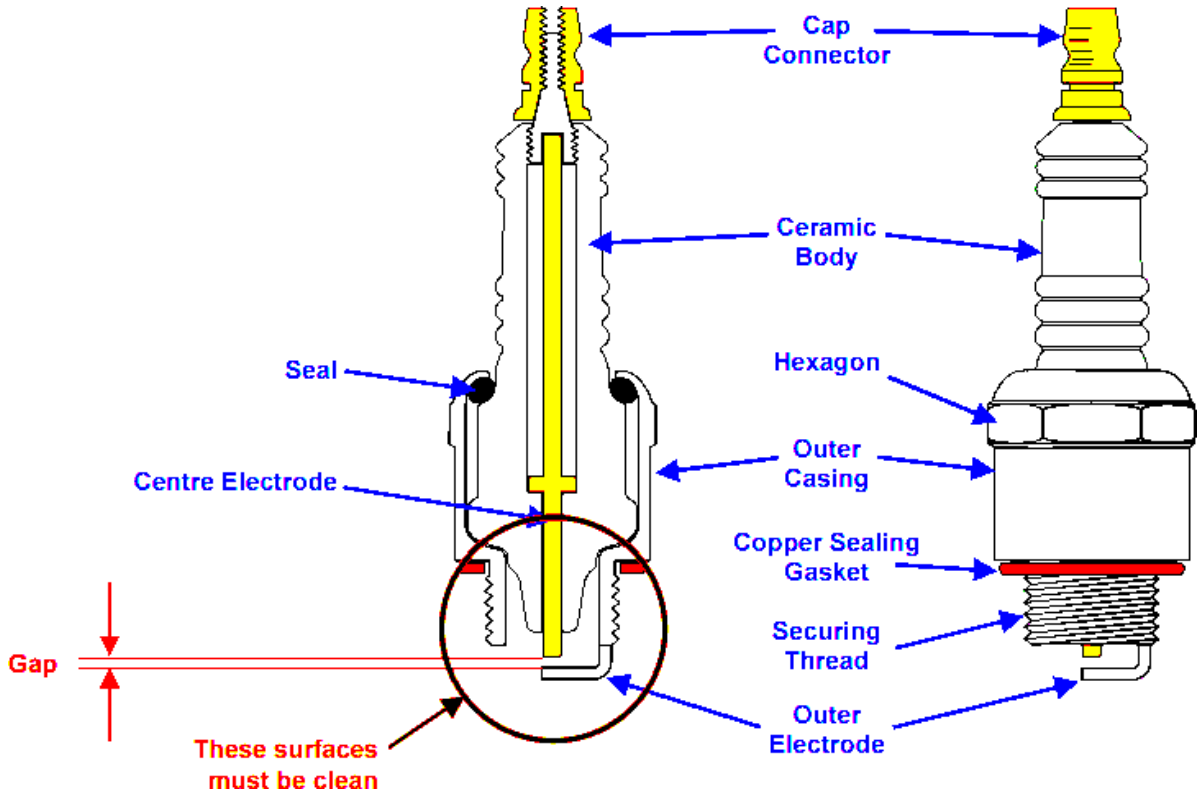
to ignite the fuel mixture. Somewhere between

4,000 and 10,000 volts are required to make

current jump the gap at the plug electrodes. This is much lower than the output potential of the coil.

Spark plug gap is the distance between the center and side electrodes. Normal gap specifications range between .030 to .060 inch. Smaller spark plugs gaps are used on older vehicles equipped with contact point ignition systems.

Spark plugs are either resistor or non-resistor types . A resistor spark plug has internal resistance (approximately 10,000 ohms) designed to reduce the static in radios. Most new vehicles require resistortype plugs. Non-resistor spark plug has a solid metal rod forming the center electrode. This type of spark plugs is NOT commonly used except for racing and off-road vehicles.



Spark Plug Heat Range and Reach:

The heat range of the spark plug determines how hot the plug will get. The length and diameter of the insulator tip and the ability of the spark plug to transfer heat into the cooling system determine spark plug heat range.

A hot spark plug has a long insulator tip that prevents heat transfer into the waterjackets. It will also bum off any oil deposits. This provides a self-cleaning action.

A cold spark plug has a shorter insulator tip

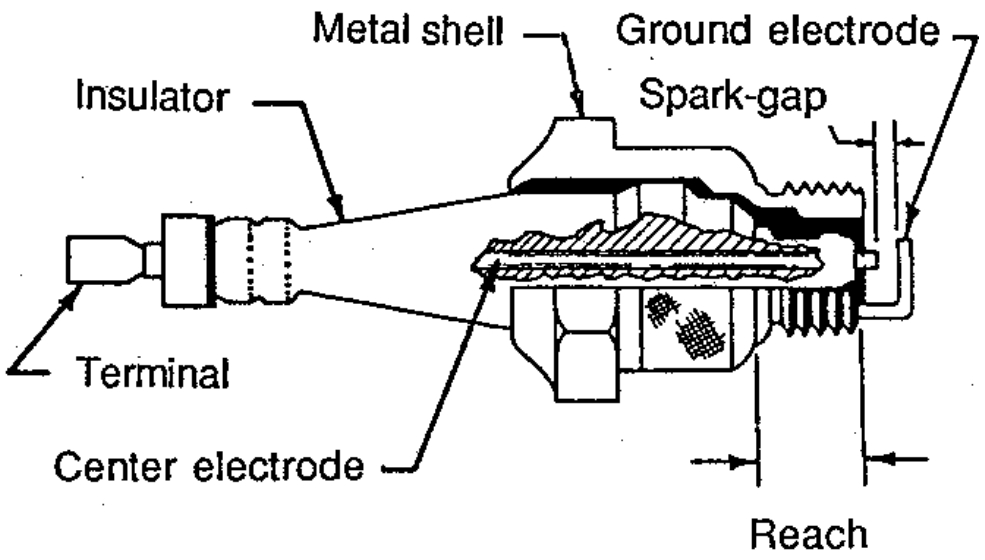
and operates at a cooler temperature. The cooler tip helps prevent overheating and preignition. A cold spark plug is used in engines operated at high speeds.

Vehicle manufacturers recommend a specific spark plug heat range for their engines. The heat range is coded and given as a number on the spark plug insulator. The larger the number on the plug, the hotter the spark plug tip will operate. For example, a 54 plug would be hotter than a 44 or 34 plug.

The only time you should change from spark plug heat range specifications is when abnormal engine or operating conditions are encountered. For instance, if the plug runs too cool, sooty carbon will deposit on the insulator around the center electrode. This deposit could soon build up enough to short out the plug. Then high voltage surges would leak across the carbon instead of producing a spark across the spark plug gap. Using a hotter plug will bum this carbon deposit away

or prevent it from forming.

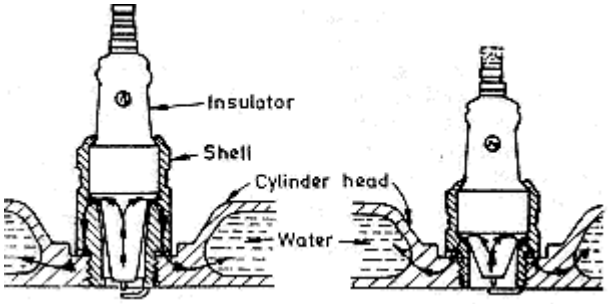
Spark plug reach is the distance between the end of the spark plug threads and the seat or sealing surface of the plug. Plug reach determines how far the plug reaches through the cylinder head. If spark plug reach is too long, the spark plug will protrude too far into the combustion chamber and the piston at TDC may strike the electrode. However, if the reach is too short, the plug electrode may not extend far enough into the cylinder head and combustion efficiency will be reduced. A spark plug must reach into the combustion chamber far enough so that the spark gap will be properly positioned in the combustion chamber without interfering with the turbulence of the air-fuel mixture or reducing combustion action.



Sectional view of a (A) non-resistor and (B) resistor spark plug.

Construction of Spark Plug:

Types of spark plugs:



Introduction to carburetor systems:

Carburetor is a device used for providing proper air/fuel mixture ratio. The carburetor works on Bernoulli's principle i.e. The faster the air moves, the lower is its static pressure, and the higher is its dynamic pressure. The throttle or accelerator linkage indirectly controls the flow of

fuel by actuating the carburetor mechanisms which meters the flow of air being pulled into the engine. The speed of this flow, and therefore its pressure, determines the amount of fuel drawn into the airstream.

The latest type of carburetor system is the electronic feedback design, which provides better combustion by improved control of the air/fuel mixture. A three-way converter not only oxidizes HC and CO but also chemically reduces oxides of nitrogen (NOX).If the air/fuel mixture is too lean, NOX is not converted efficiently. If the mixture is too rich, HC and CO does not oxidize efficiently. Monitoring the air/fuel ratio is the job of the exhaust gas oxygen sensor.

An oxygen sensor senses the amount of oxygen present in the exhaust stream. A lean mixture produces a high level of oxygen in the exhaust. The oxygen sensor, placed in the exhaust before the catalytic converter, produces a voltage signal that varies with the amount of

oxygen the sensor detects in the exhaust. If the oxygen level is high (a lean mixture), the voltage output is low. If the oxygen level is low (a rich mixture), the voltage output is high.The electrical output of the oxygen sensor is monitored by an electronic control unit (ECU). This microprocessor is programmed to interpret the input signals from the sensor and in turn generate output signals to a mixture control device that meters more or less fuel into the air charge as it is needed to maintain the 14.7 to 1 ratio.

Whenever these components are working to control the air/fuel ratio, the carburetor is said to be operating in closed loop. The oxygen sensor is constantly monitoring the oxygen in the exhaust, and the control module is constantly making adjustments to the air/fuel mixture based on the fluctuations in the sensor's voltage output. However, there are certain conditions under which the control module ignores the signals from the oxygen sensor and does not regulate the ratio of

fuel to air. During these times, the carburetor is functioning in conventional manner and is said to be operating in open loop. (The control cycle has been broken.)

The carburetor operates in open loop until the oxygen sensor reaches a certain temperature (approximately 600F). The carburetor also goes into open loop when a richer-than- normal air/fuel mixture is required, such as during warm-up and heavy throttle application.
Several other sensors are needed to alert the electronic sensor provides input relating to engine temperature. A vacuum sensor and a throttle position sensor indicate wide open throttle.

Early feedback systems used a vacuum switch to control metering devices on the carburetor. Closed loop signals from the electronic control module are sent to a vacuum solenoid regulator, which in turn controls vacuum to a piston and diaphragm assembly in the carburetor. The vacuum diaphragm and a spring

above the diaphragm work together to lift and lower a tapered fuel metering rod that moves in and out of an auxiliary fuel jet in the bottom of the fuel bowl. The position of the metering rod in the jet controls the amount of fuel allowed to flow into the main fuel well.

A less common method to control the air/fuel mixture is with a back suction system feedback. The back suction system consists of an electric stepper motor, a metering pintle valve, an internal vent restrictor, and a metering orifice. The stepper motor regulates the pintle movement in the metering orifice, thereby varying the area of the opening communicating control vacuum to the fuel bowl. The larger this area, the leaner the air/fuel mixture. Some of the control vacuum is bled off through the internal vent restrictor. The internal vent restrictor also serves to vent the fuel bowl when the back suction control pintle is in the closed position.

COOLING SYSTEM

A system, which controls the engine temperature, is known as a cooling system.

NECESSITY OF COOLING SYSTEM

The cooling system is provided in the IC engine for the following reasons:

- The temperature of the burning gases in the engine cylinder reaches up to 1500 to 2000°C, which is above the melting point of the material of the cylinder body and head of the engine. (Platinum, a metal which has one of the highest melting points, melts at 1750 °C, iron at 1530°C and aluminium at 657°C.) Therefore, if the heat is not dissipated, it would result in the failure of the cylinder material.
- Due to very high temperatures, the film of the lubricating oil will get oxidized, thus producing carbon deposits on the surface. This will result in piston seizure.
- Due to overheating, large temperature differences may lead to a distortion of the engine components due to the thermal stresses set up. This makes it necessary for, the temperature variation to be kept to a minimum.
- Higher temperatures also lower the volumetric efficiency of the engine.
-

REQUIREMENTS OF EFFICIENT COOLING SYSTEM

The two main requirements of an efficient cooling system are:

1. It must be capable of removing only about 30% of the heat generated in the combustion chamber. Too much removal of heat lowers the thermal efficiency of the engine.
2. It should remove heat at a fast rate when the engine is hot. During the starting of the engine, the cooling should be very slow so that the different working parts reach their operating temperatures in a short time.

TYPES OF COOLING SYSTEM

There are two types of cooling systems:

(i) Air cooling system and
(ii) Water-cooling system.

AIR COOLING SYSTEM

In this type of cooling system, the heat, which is conducted to the outer parts of the engine, is radiated and conducted away by the stream of air, which is obtained from the atmosphere. In order to have efficient cooling by means of air, providing fins around the cylinder and cylinder head increases the contact area. The fins are metallic ridges, which are formed during the casting of the cylinder and cylinder head

The amount of heat carried off by the air-cooling depends upon the following factors:

(i) The total area of the fin surfaces,
(ii) The velocity and amount of the cooling air and
(iii) The temperature of the fins and of the cooling air.

Air-cooling is mostly tractors of less horsepower, motorcycles, scooters, small cars and small aircraft engines where the forward motion of the machine gives good velocity to cool the engine. Air-cooling is also provided in some small industrial engines. In this system, individual cylinders are generally employed to provide ample cooling area by providing fins. A blower is used to provide air.

Advantages of Air Cooled Engines

Air cooled engines have the following advantages:

1. Its design of air-cooled engine is simple.
2. It is lighterin weight than water-cooled engines due to the absence of water jackets, radiator, circulating pump and the weight of the cooling water.
3. It is cheaper to manufacture.
4. It needs less care and maintenance.
5. This system of cooling is particularly advantageous where there are extreme climatic conditions in the arctic or where there is scarcity of water as in deserts.
6. No risk of damage from frost, such as cracking of cylinder jackets or radiator water tubes.

WATER COOLING SYSTEM

It serves two purposes in the working of an engine:

a) It takes away the excessive heat generated in the engine and saves it from over heating.
b) It keeps the engine at working temperature for efficient and economical working. This cooling system has four types of systems:

(i) Direct or non-return system,
(ii) Thermo-Syphone system,
(iii) Hopper system and
(iv) Pump/forced circulation system.

Though the present tractor has a forced circulation system, it is still

worthwhile to get acquainted with the other three systems.

Non-Return Water Cooling System

This is suitable for large installations and where plenty of water is available. The water from a storage tank is directly supplied to the engine cylinder. The hot water is not cooled for reuse but simply discharges. The low H.P. engine, coupled with the irrigation pump is an example.

Thermo-Syphone Water Cooling System

This system works on the principle that hot water being lighter rises up and the cold water being heavier goes down. In this system the radiator is placed at a higher level than the engine for the easy flow of water towards the engine. Heat is conducted to the water jackets from where it is taken away due to convection by the circulating water. As the water jacket becomes hot, it rises to the top of the radiator. Cold water from the radiator takes the place of the rising hot water and in this way a circulation of water is set up m the system. This helps in keeping the engine at working temperature.

Disadvantages of Thermo-Syphone System

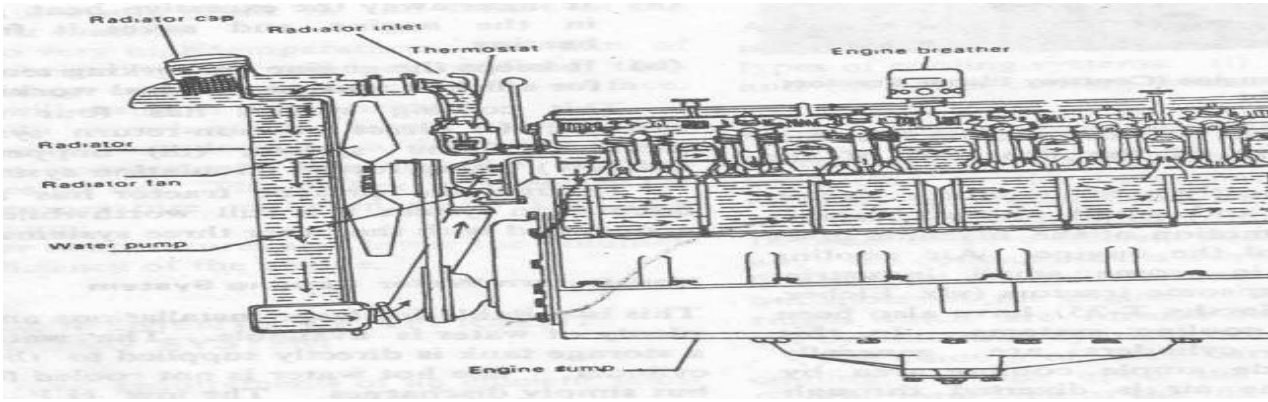
1 Rate of circulation is too slow.
2. Circulation commences only when there is a marked difference in temperature.
3. Circulation stops as the level of water falls below the top of the delivery pipe of the radiator. For these reasons this system has become obsolete and is no more in use.

Hopper Water Cooling System

This also works on the same principle as the thermo-syphone system. In this there is a hopper on a jacket containing water, which surrounds the engine cylinder. In this system, as soon as water starts boiling, it is replaced by cold water. An engine fitted with this system cannot run for several hours without it being refilled with water.

Force Circulation Water Cooling System

This system is similar in construction to the thermo-syphone system except that it makes use of a centrifugal pump to circulate the water throughout the water jackets and radiator



The water flows from the lower portion of the radiator to the water jacket of the engine through the centrifugal pump. After the circulation water comes back to the radiator, it loses its heat by the process of radiation. This system is employed in cars, trucks, tractors, etc.

Parts of Liquid Cooling System

The main parts in the water-cooling system are: (i) water pump, (ii) fan, (iii) radiator and pressure cap, (iv) fan belt (v) water jacket, (vi) thermostat valve, (vii) temperature gauge and (viii) hose pipes.

Water Pump

This is a centrifugal type pump. It is centrally mounted at the front of the cylinder block and is usually driven by means of a belt. This type of pump consists of the following parts: (i) body or casing, (ii) impeller (rotor), (iii) shaft, (iv) bearings, or bush, (v) water pump seal and (vi) pulley.

The bottom of the radiator is connected to the suction side of the pump. The power is transmitted to the pump spindle from a pulley mounted at the end of the crankshaft.

Seals of various designs are incorporated in the pump to prevent loss of coolant from the system.

Fan

The fan is generally mounted on the water pump pulley, although on some engines it is attached directly to the crankshaft. It serves two purposes in the cooling system of a engine.

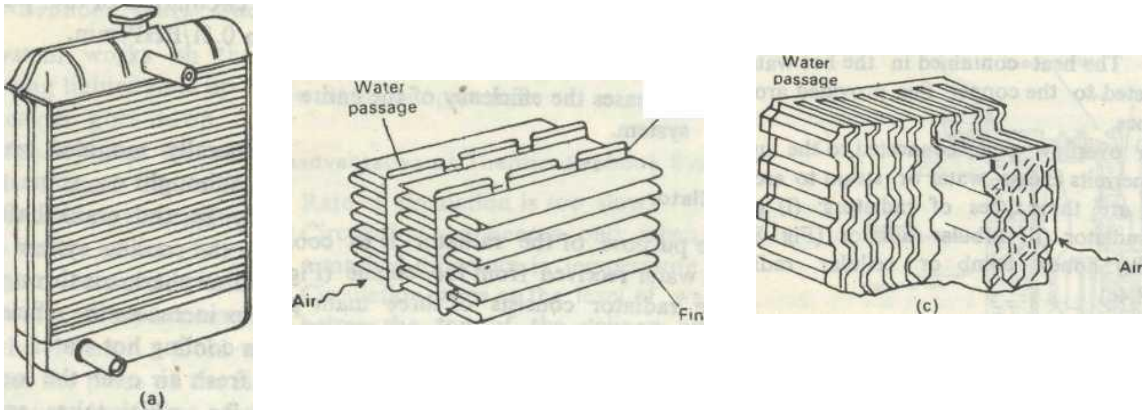
(a) It draws atmospheric air through the radiator and thus increases the efficiency of the radiator in cooling hot water.

(b) It throws fresh air over the outer surface of the engine, which takes away the heat conducted by the engine parts and thus increases the efficiency of the entire cooling system.

Radiator

The purpose of the radiator is to cool down the water received from the engine. The radiator consists of three main parts: (i) upper tank, (ii) lower tank and (iii) tubes.

Hot water from the upper tank, which comes from the engine, flows downwards through the tubes. The heat contained in the hot water is conducted to the copper fins provided around the tubes.
An overflow pipe, connected to the upper[1] tank, permits excess water or steam to escape. There are three types of radiators: (i) gilled tube radiator, (ii) tubular radiator (Fig. b)
and (iii) honey comb or cellular radiator (Fig. c)



Type of radiators

Gilled tube radiator:
This is perhaps the oldest type of radiator, although it is still in use. In this, water flows inside the tubes. Each tube has a large number of annular rings or fins pressed firmly over its outside surface.
Tubular radiator: The only difference between a gilled tubes radiator and a tubular one is that in this case there are no separate fins for individual tubes. The radiator vertical tubes pass through thin fine copper sheets which run horizontally.
Honey comb or cellular radiator: The cellular radiator consists of a large number of individual air cells which are surrounded by water. In this, the clogging of any passage affects only a small parts of the cooling surface. However, in the tubular radiator, if one tube becomes clogged, the cooling effect of the entire tube is lost.

Thermostat Valve
It is a kind of check valve which opens and closes with the effect of temperature. It is fitted in the water outlet of the engine. During the warm-up period, the thermostat is closed and the water pump circulates the water only throughout the cylinder block and cylinder head. When the normal operating temperature is reached, the thermostat valve opens and allows hot water to flow towards the radiator

Standard thermostats are designed to start opening at 70 to 75°C and they fully open at 82°C. High temperature thermostats, with permanent anti-freeze solutions (Prestine, Zerex, etc.), start opening at 80 to 90°C

and fully open at 92°C.

Types of thermostat

There are three types of thermostats: (i) bellow type, (ii) bimetallic type and (iii) pellet type.

Bellow type valve: Flexible bellows are filled with alcohol or ether. When the bellows is heated, the liquid vaporises, creating enough pressure to expand the bellows. When the unit is cooled, the gas condenses. The pressure reduces and the bellows collapse to close the valve.

Bimetallic type valve: This consists of a bimetallic strip. The unequal expansion of two metallic strips causes the valve to open and allows the water to flow in the radiator.

Pellet type valve: A copper impregnated wax pellet expands when heated and contracts when cooled. The pellet is connected to the valve through a piston, such that on expansion of the
pellet, it opens the valve. A coil spring closes the valve when the pellet contracts.

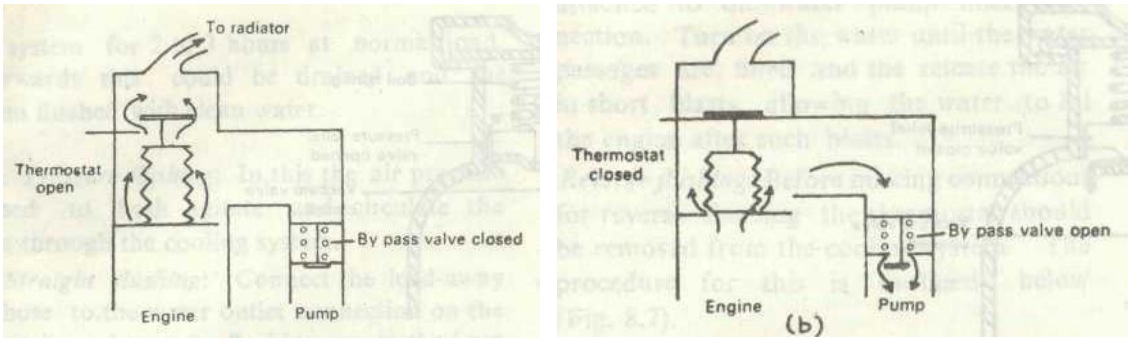
PRESSURE COOLING SYSTEM

In the case of the ordinary water-cooling system where the cooling water is subjected to atmospheric pressure, the water boils at 212°F. But when water is boiled in a closed radiator under high pressure, the boiling temperature of water increases. The higher water temperature gives more efficient engine performance and affords additional protection under high altitude and tropical conditions for long hard driving periods. Therefore, a pressure-type radiator cap is used with the forced circulation cooling system (Fig. 8.6a). The cap is fitted on the radiator neck with an air tight seal. The pressure-release valve is set to open at a pressure between 4 and 13 psi. With this increase in pressure, the boiling temperature of water increases to 243°F (at 4 psi boiling tap 225°F and 13 psi boiling temperature 243°F). Any increase in pressure is released by the pressure release valve to the atmosphere. On cooling, the vapours will condense and a partial vacuum will be created which will result in the collapse of the hoses and tubes. To overcome this problem the pressure

release valve is associated with a vacuum valve which opens the radiator to the atmosphere.

ANTI-FREEZE SOLUTIONS

In order to prevent the water in the cooling system from freezing, some chemical solutions which are known as anti-freeze solutions are mixed with water. In cold areas, if the engine is kept without this solution for some time, the water may freeze and expand leading to fractures in the cylinder block, cylinder head, pipes and/or radiators.
The boiling point of the anti-freeze solution should be as high as that of water. An ideal mixture should easily dissolve in water, be reasonably cheap and should not deposit any foreign matter in the jacket pipes and radiator.



No single anti-freeze solution satisfies all these requirements. The materials commonly used are wood

alcohol, denatured alcohol, glycerine, ethylene, glycol, propylene glycol, mixtures of alcohol and glycerine and various mixtures of other chemicals.

SERVICING & CLEANING OF COOLING SYSTEM

For smooth and trouble-free service, the cooling system should be cleaned at periodic intervals to prevent the accumulation of excessive rust and scale. The commercial cleaning compounds available must be carefully used in accordance with the manufacturers' instructions.
A general cleaning procedure is outlined below. If a considerable amount of scale and rust has accumulated, it may not be possible that cleaning alone will remove it. In that case, the radiator and engine water jackets must be flushed out with special air pressure guns.

Cooling System Cleaning Procedure

It involves the following steps.

1. Drain the system by opening the drain cocks. Prepare a solution of washing soda and water, with a ratio of 1 kg soda to 10 litres of water. Fill up this solution in the radiator and engine block and run the engine on idle load for 8 to 10 hours. Drain this solution and flush the system

with clean water.

2. In case the scale formulation is bard and cannot be completely removed with washing soda, another cleaning agent can be prepared with 40 parts of water, 5 parts of commercial hydrochloric acid and 1 part of formaldehyde. This solution is allowed to remain in the system for 2 to 3 hours at normal load. Afterwards this could be drained and the system flushed with clean water.
3. *Pressure flushing:* In this the air pressure is used to both agitate and circulate the water through the cooling system.

(a) *Straight flushing:* Connect the lead-away hose to the water outlet connection on the engine. Insert the flushing gun in the hose attached to the water pump inlet connection. Turn on the water until the water passages are filled and the release the air in short blasts, allowing the water to fill the engine after such blasts.

(b) *Reverse flushing:* Before making connections for reverse flushing the thermostat should be removed from the cooling system. The procedure for this is outlined below:

(i) *Radiator:* Disconnect the top hose of the radiator from the engine and attach a lead-away hose to the radiator. Disconnect the bottom of the radiator from water pump and attach the flushing gun. Connect water and air hoses to the gun. Turn on the water and fill the radiator to the top. Release the air in short blasts and allows the water to fill the radiator between each blast. Continue the operation until the water from the lead-away hose is clear, (ii) *Engine:* Connect the lead-away hose to the inlet of the water pump and the flushing gun to the water outlet of the pump on the cylinder head. Follow the same procedure.

LUBRICATION SYSTEM

IC. engine is made of many moving parts. Due to continuous movement of two metallic surfaces over each other, there is wearing moving parts, generation of heat and loss of power in the engine lubrication of moving parts is essential to prevent all these harmful effects.

PURPOSE OF LUBRICATION

Lubrication produces the following effects: (a) Reducing friction effect (b) Cooling effect (c) Sealing effect and (d) Cleaning effect.

(a) Reducing frictional effect: The primary purpose of the lubrication is to reduce friction and wear between two rubbing surfaces. Two rubbing surfaces always produce friction. The continuous friction produce heat which causes wearing of parts and loss of power. In order to avoid friction, the contact of two sliding surfaces must be reduced as far a possible. This can be done by proper lubrication only. Lubrication forms an oil film between two moving surfaces. Lubrication also reduces noise

produced by the movement of two metal surfaces over each other.

(b) Cooling effect: The heat, generated by piston, cylinder, and bearings is removed by lubrication to a great extent. Lubrication creates cooling effect on the engine parts.

(c) Sealing effect: The lubricant enters into the gap between the cylinder liner, piston and piston rings. Thus, it prevents leakage of gases from the engine cylinder.

(d) Cleaning effect: Lubrication keeps the engine clean by removing dirt or carbon from inside of the engine along with the oil.

Lubrication theory: There are two theories in existence regarding the application of lubricants on a surface: (i) Fluid film theory and (ii) Boundary layer theory.

(i) **Fluid film theory:** According to this theory, the lubricant is, supposed to act like mass of globules, rolling in between two surfaces. It produces a rolling effect, which reduces friction.

(ii) **Boundary layer theory:** According to this theory, the lubricant is soaked in rubbing surfaces and forms oily surface over it. Thus the sliding surfaces are kept apart from each other, thereby reducing friction.

TYPES OF LUBRICANTS

Lubricants are obtained from animal fat, vegetables and minerals Lubricants made of animal fat, does not stand much heat. It becomes waxy and gummy which is not very suitable for machines.

Vegetable lubricants are obtained from seeds, fruits and plants. Cottonseed oil, olive oil, linseed oil and castor oil are used as lubricant in small Simple machines.

Mineral lubricants are most popular for engines and machines. It is obtained from crude petroleum found in nature. Petroleum lubricants are less expensive and suitable for internal combustion engines. A good lubricant should have the following qualities:

1. It should have sufficient viscosity to keep the rubbing surfaces apart
2. It should remain stable under changing temperatures.
3. It should keep lubricated pans clean.
4. It should not corrode metallic surfaces.

ENGINE LUBRICATING SYSTEM

The lubricating system of an engine is an arrangement of mechanism and devices which maintains supply of lubricating oil to the rubbing surface of an engine at correct pressure and temperature.

The parts which require lubrication are: (i) cylinder walls and piston (ii) piston pin (iii) crankshaft and connecting rod bearings (iv) camshaft bearings (v) valves and valve operating mechanism (vi) cooling fan (vii) water pump and (viii) ignition mechanism.

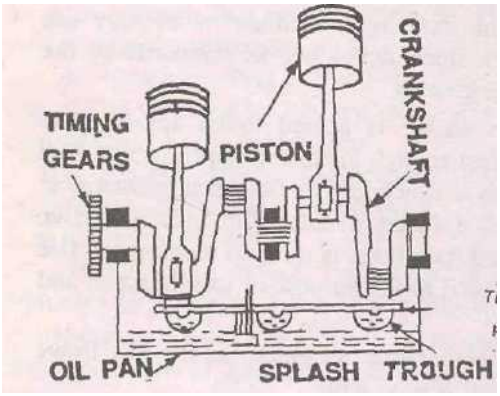
There are three common systems of lubrication used on stationary engines, tractor engines and automobiles:

(i) Splash system (ii) Forced feed system and (iii) Combination of splash

and forced feed system.

SPLASH SYSTEM

In this system, there is an oil trough, provided below the connecting rod. Oil is maintained at a uniform level in the oil trough. This is obtained by maintaining a continuous flow of oil from the oil sump or reservoir into a splash pan, which has a depression or a trough like arrangement under each connecting rod. This pan receives its oil supply from the oil sump either by means of a gear pump or by gravity. A dipper is provided at the lower end of the connecting rod. This dipper dips into to oil trough and splashes oil out of the pan. The splashing action of oil maintains a fog or mist of oil that drenches the inner parts of the engine such as bearings, cylinder walls, pistons, piston pins, timing gears etc.



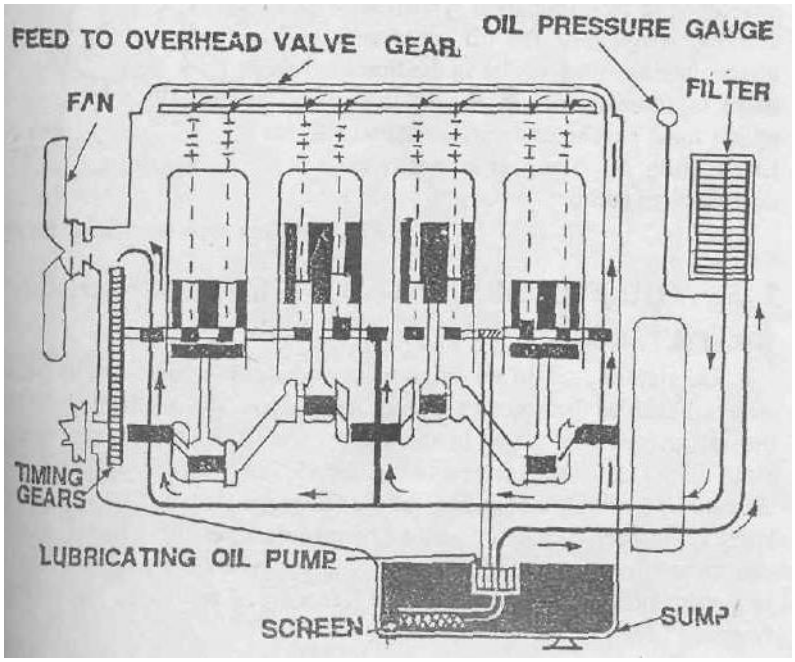
Splash lubrication system

This system is usually used on single cylinder engine with closes crankcase. For effective functioning of the engine, proper level of oil maintained in the oil pan.
Lubrication depends largely upon the size of oil holes and clearances. This system is very effective if the oil is clean and undiluted. Its disadvantages are that lubrication is not very uniform and when the rings are worn, the oil passes the piston into combustion chamber, causing carbon deposition, blue smoke and spoiling the plugs. There is every possibility that oil may become very thin through crankcase dilution. The worn metal, dust and carbon may be collected in the oil chamber and be carried to different parts of the engine, causing wear and tear.

FORCED FEED SYSTEM

In this system, the oil is pumped directly lo the crankshaft, connecting rod, piston pin, timing gears and camshaft of the engine through suitable paths

of oil. Usually the oil first enters the main gallery, which may be a pipe or a channel in the crankcase casting. From this pipe, it goes to each of the main bearings through holes. From main bearings, it goes to big end bearings of connecting rod through drilled holes in the crankshaft. From there, it goes to lubricate the walls, pistons and rings. There is separate oil gallery to lubricate timing gears. Lubricating oil pump is a positive displacement pump, usually gear type or vane' type. The oil also goes to valve stem and rocker arm shaft under pressure through an oil gallery.

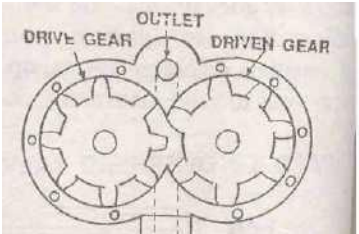


Forced feed lubrication system

The excess oil comes back from the cylinder head to the crankcase. The pump discharges oil into oil pipes, oil galleries or ducts, leading different parts of the engine. This system is commonly used on high speed multi-cylinder engine in tractors, trucks and automobiles.

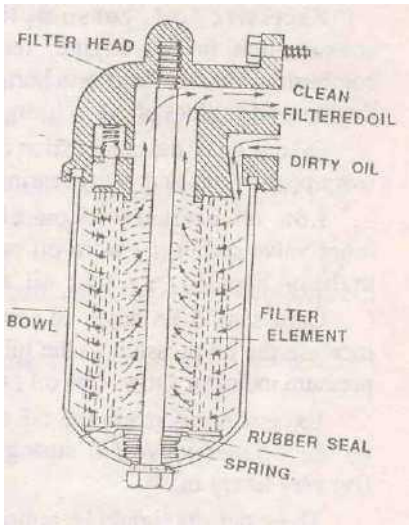
COMBINATION OF SPLASH AND FORCED FEED SYSTEM In this system, the engine component, which are subjected to very heavy load are lubricated under forced pressure, such as main bearing connecting rod bearing and camshaft bearing. The rest of the parts like cylinder liners, cams, tappets etc are lubricated by splashed oil.

Oil pump: Oil pump is usually a gear type pump, used to force oil into the oil pipe. The pump is driven by the camshaft of t engine. The lower end of the pump extends down into the crankcase which is covered with a screen to check foreign particles. A portion of the oil forced to the oil filter and the remaining oil goes to lubricate various par of the engine. An oil pressure gauge fitted in the



line, indicates the oil pressure in the lubricating system. About 3 kg/sq cm (45 psi) pressure is developed in the lubrication system of a tractor engine, [f the oil pressure gauge indicates no pressure in the line, there is some defect in the system which must be checked immediately. Lubricating oil pump is a positive displacement pump.

OIL FILTER: Lubricating oil in an engine becomes contaminated with various materials such as dirt, metal particles and carbon. Oil filler removes the dirty elements of the oil in an effective way. It is a type of strainer using cloth, paper, felt, wire screen or similar elements. Some oil filter can be cleaned by washing, but in general old filters are replaced by new filters at specified interval of time prescribed by manufacturers. Wearing of parts, oil consumption and operating cost of an engine can be considerably reduced by proper maintenance of oil filters. Oil filters are of two types: (i) Full-flow filter and (ii) By-pass filler.



(i) Full flow filter: In this filter the entire quantity of oil is forced to circulate through it before it enters the engine. A spring loaded valve is usually fitted in the filter as a protection device against oil starvation in case of filter getting clogged. Filter element consists of felt, cloth, paper and plastic. All these elements are replaceable and should be changed after the recommended period.

(ii) By pass filter: In this type of filter, the supply lines are from the pump and are connected to permit only a part of the oil. Through the filter the balance oil reaches directly to the engine parts. Over a period of operation, all the oil in the crankcase passes through the filter.

Oil pressure gauge: Oil pressure gauge is used to indicate the oil pressure in the oil lines. It serves to warn the operator of any irregularity in the system.

Crankcase breather: The engine crankcase is always fitted with some kind of breather, connecting the space above the oil level with the outside atmosphere. The purpose of the breather is to prevent building up pressure in the crankcase.

Relief valve: Relief valve is provided to control the quantity of oil circulation and to maintain correct pressure in the lubricating system.

TROUBLES IN LUBRICATION SYSTEM

There are a few common troubles in lubrication system such as: (1) Excessive oil consumption (2) Low oil pressure and (3) Excessive oil pressure-

Excessive oil consumption: When there is excessive oil consumption in the engine, the reasons arc : (a) more oil goes to combustion chamber and gets burnt (b) some leakage occurs in some part of - the line and (c) loss of oil in form of vapour through ventilating system. Oil can enter the combustion chamber through rings and cylinder walls, worn piston rings and worn bearings.

Low oil pressure: Low oil pressure can result due to: (i) weak relief valve spring (ii) worn oil pump (iii) cracked oil line (iv) obstruction in the oil lines (v) very thin oil and (vi) worn out bearings.

Care should be taken to remove these defects as far as possible to increase the oil pressure in the lubricating system. Sometimes defective oil pressure indicator shows low oil pressure. This should be checked.

Excessive oil pressure: Excessive oil pressure may result due to : (i) stuck relief valve (ii) strong valve spring (iii) clogged oil line and (iv) very heavy oil.

These defects should be removed to reduce the excessive oil pressure in the lubricating system. Sometimes defective oil pressure indicator records high oil pressure. Care should be taken to check this defect.

CARE AND MAINTENANCE OF LUBRICATION SYSTEM

The following are few suggestions for good lubrication system:

- A good design of oil circulation system should be chosen.
- Correct grade of lubricant ensures long and trouble free service.
- Oil should be maintained at desired level in the oil chamber.
- Oil should be cleaned regularly and after specified period of use, old filters should be replaced by new filters.
- Connections, pipings, valves and pressure gauge should be checked regularly.
- Oil should be changed regularly after specified interval of time. Before putting the new oil, the crankcase should be cleaned and flushed well with a flushing oil.
- Precautions should be taken to keep the oil free from dust and water.

Hybrid Electrical Vehicles

Introduction

A hybrid electric vehicle (HEV) has two types of energy storage units, electricity and fuel. Electricity means that a battery (sometimes assisted by ultracaps) is used to store the energy, and that an electromotor (from now on called *motor*) will be used as traction motor.
Fuel means that a tank is required, and that an Internal Combustion Engine (ICE, from now on called *engine*) is used to generate mechanical power, *or* that a fuel cell will be used to convert fuel to electrical energy. In the latter case, traction will be performed by the electromotor only. In the first case, the vehicle will have both an engine and a motor.

- Depending on the drive train structure (how motor and engine are connected), we can distinguish between parallel, series or combined HEVs. This will be explained in paragraph 1.
- Depending on the share of the electromotor to the traction power, we can distinguish between mild or micro hybrid (start-stop systems), power assist hybrid, full hybrid and plug-in hybrid. This will be explained in paragraph 2.
- Depending on the nature of the non-electric energy source, we can distinguish between combustion (ICE), fuel cell, hydraulic or pneumatic power, and human power. In the first case, the ICE is a spark ignition engines (gasoline) or compression ignition direct injection (diesel) engine. In the first two cases, the energy conversion unit may be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels.

Motors are the "work horses" of Hybrid Electric Vehicle drive systems. The electric traction motor drives the wheels of the vehicle. Unlike a traditional vehicle, where the engine must "ramp up" before full torque can be provided, an electric motor provides full torque at low speeds. The motor also has low noise and high efficiency. Other characteristics include excellent "off the line" acceleration, good drive control, good fault tolerance and flexibility in relation to voltage fluctuations.
The front-running motor technologies for HEV applications include PMSM (permanent magnet synchronous motor), BLDC (brushless DC motor), SRM (switched reluctance motor) and AC induction motor.
A main advantage of an electromotor is the possibility to function as generator. In all HEV systems, mechanical braking energy is regenerated.
The max. operational braking torque is less than the maximum

traction torque; there is always a mechanical braking system integrated in a car.

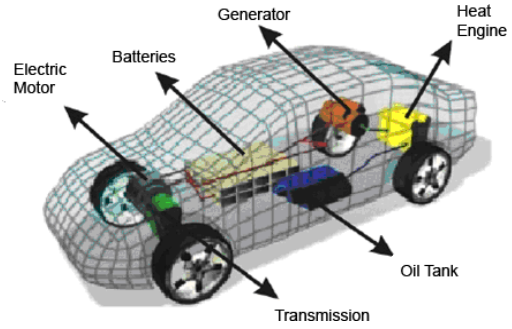
The battery pack in a HEV has a much higher voltage than the SIL automotive 12 Volts battery, in order to reduce the currents and the I^2R losses.

Accessories such as power steering and air conditioning are powered by electric motors instead of being attached to the combustion engine. This allows efficiency gains as the accessories can run at a constant speed or can be switched off, regardless of how fast the combustion engine is running.
Especially in long haul trucks, electrical power steering saves a lot of energy.

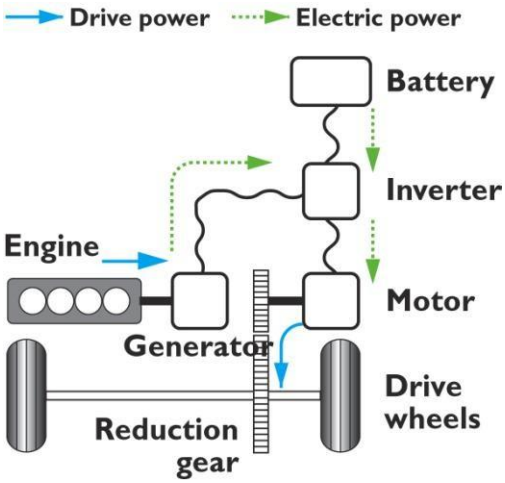
1. Types by drivetrain structure

Series hybrid

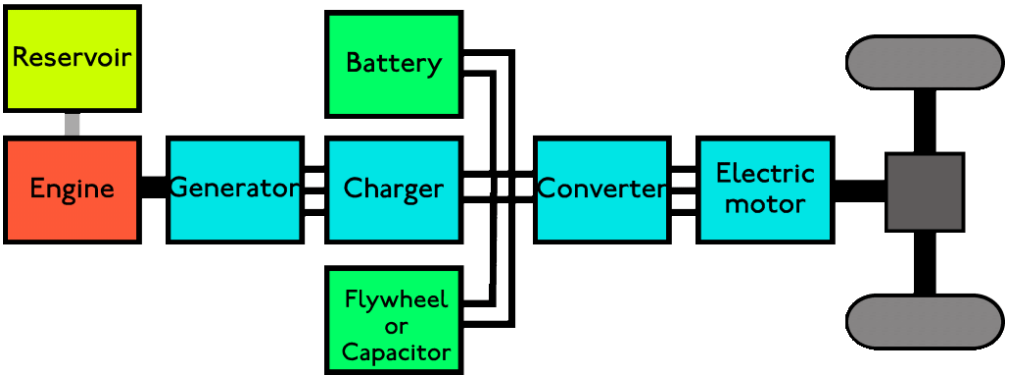
In a series hybrid system, the combustion engine drives an electric generator (usually a three-phase alternator plus rectifier) instead of directly driving the wheels. The electric motor is the only means of providing power to the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator.



Series hybrid configurations already exist a long time: diesel-electric locomotives, hydraulic earth moving machines, diesel-electric power groups, loaders.



Structure of a series hybrid vehicle (below with flywheel or ultracaps as peak power unit)



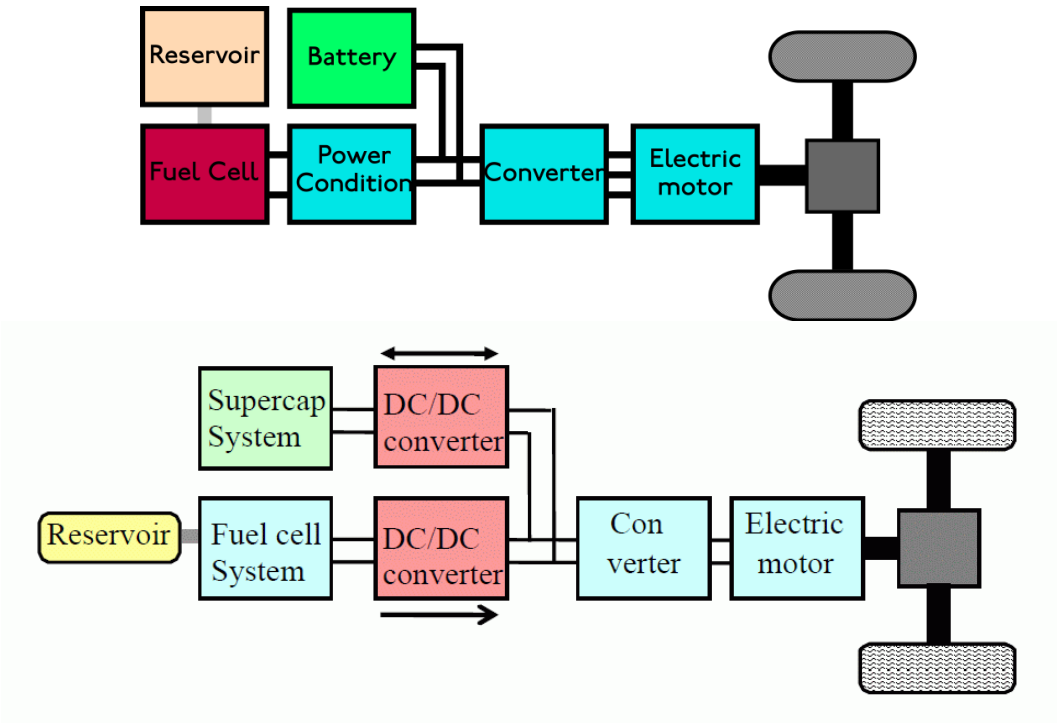
Series hybrids can be assisted by ultracaps (or a flywheel: KERS=Kinetic Energy Recuperation System), which can improve the efficiency by minimizing the losses in the battery. They deliver peak energy during acceleration and take regenerative energy during braking. Therefore, the ulracaps are kept charged at low speed and almost empty at top speed. Deep cycling of the battery is reduced, the stress factor of the battery is lowered.

A complex transmission between motor and wheel is not needed, as electric motors are efficient over a wide speed range. If the motors are attached to the vehicle body, flexible couplings are required.

Some vehicle designs have separate electric motors for each wheel. Motor integration into the wheels has the disadvantage that the unsprung mass increases, decreasing ride performance. Advantages of individual wheel motors include simplified traction control (no conventional mechanical transmission elements such as gearbox, transmission shafts, differential), all wheel drive, and allowing lower floors, which is useful for

buses. Some 8x8 all-wheel drive military vehicles use individual wheel motors.

A fuel cell hybrid electric always has a series configuration: the engine-generator combination is replaced by a fuel cell.



Structures of a fuel cell hybrid electric vehicle

Weaknesses of series hybrid vehicles:

- The ICE, the generator and the electric motor are dimensioned to handle the full power of the vehicle. Therefore, the total weight, cost and size of the powertrain can be excessive.
- The power from the combustion engine has to run through both the generator and electric motor. During long-distance highway driving, the total efficiency is inferior to a conventional transmission, due to the several energy conversions.

Advantages of series hybrid vehicles:

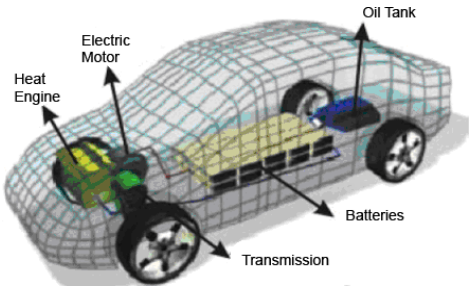
- There is no mechanical link between the combustion engine and the wheels. The engine-generator group can be located everywhere.
- There are no conventional mechanical transmission elements (gearbox, transmission shafts).
  Separate electric wheel motors can be implemented easily.
- The combustion engine can operate in a narrow rpm range (its most efficient range), even as the car changes speed.

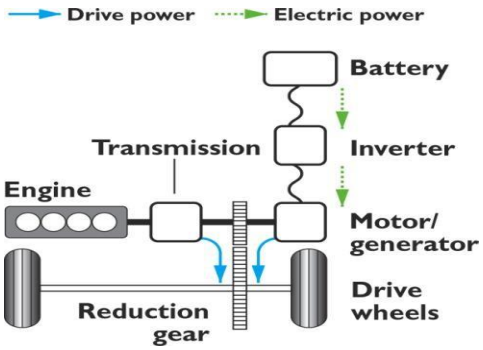
- Series hybrids are relatively the most efficient during stop-and-go city driving.

Example of SHEV: Renault Kangoo.

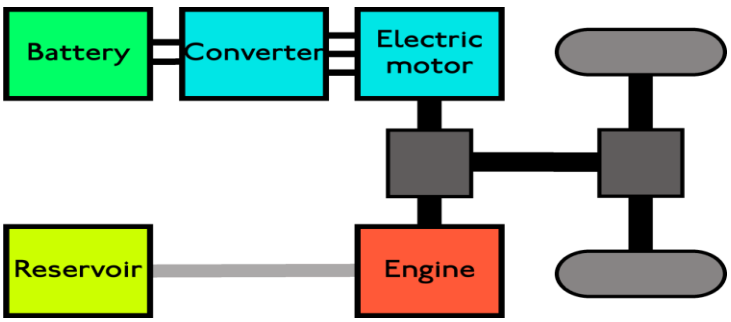
Parallel hybrid

Parallel hybrid systems have both an internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission.





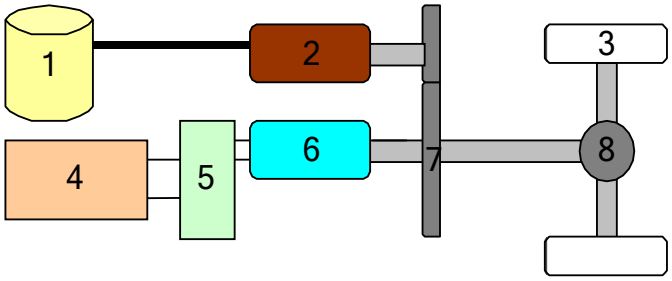
Structure of a parallel hybrid electric vehicle



Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator (see

figures above). The battery can be recharged during regenerative breaking, and during cruising (when the ICE power is higher than the required power for propulsion). As there is a fixed mechanical link between the wheels and the motor (no clutch), the battery cannot be charged when the car isn't moving.

When the vehicle is using electrical traction power only, or during brake while regenerating energy, the ICE is not running (it is disconnected by a clutch) or is not powered (it rotates in an idling manner).



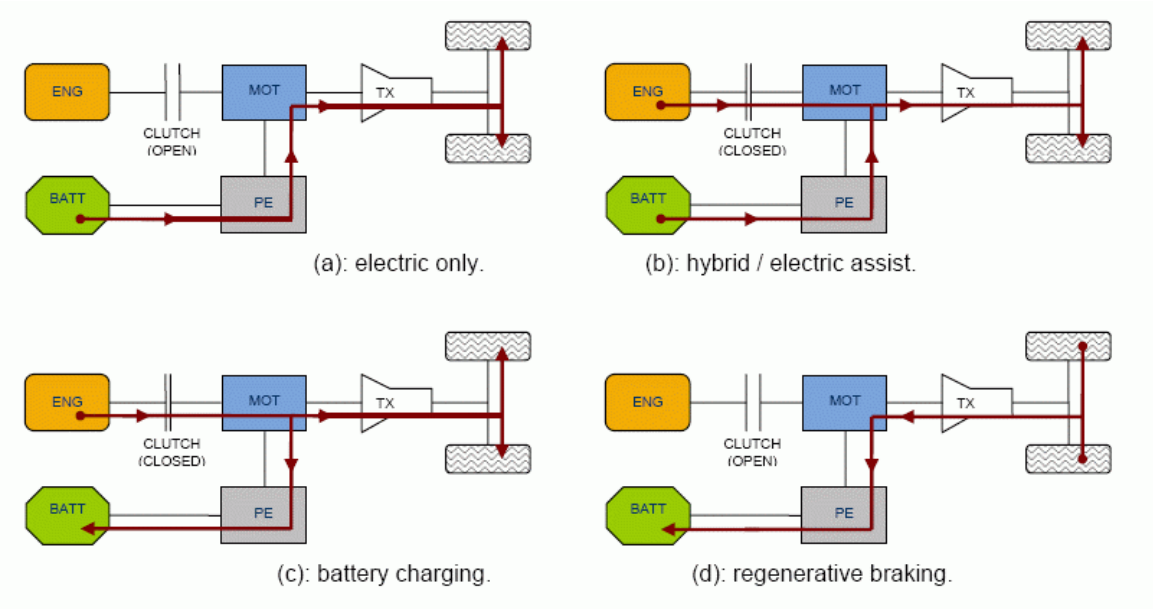
1: Fuel tank
2: Engine
3: Wheels
4: Battery
5: Converter
6: Electric Motor
7: Reduction gear
8: Differential

$$\omega_8 = \omega_6 = \omega_2 / x_2$$

$$T_8 = \frac{T_6}{\eta_6} + \frac{x_2 \cdot T_2}{\eta_2}$$

Operation modes:

The parallel configuration supports diverse operating modes:



Some typical modes for a parallel hybrid configuration PE = Power electronics
TX = Transmission

(a) electric power only: Up to speeds of usually 40 km/h, the electric motor works with only the energy of the batteries, which are not recharged by the ICE. This is the usual way of operating around the city, as well as in reverse gear, since during reverse gear the speed is limited.

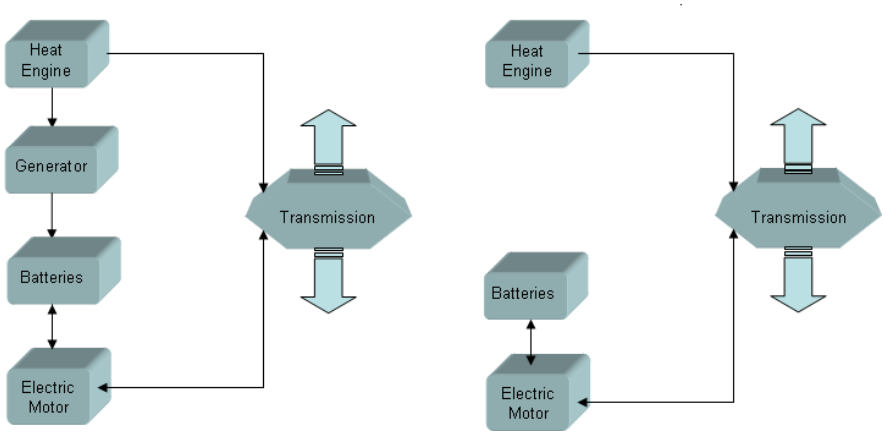
(b) ICE power only: At speeds superior to 40 km/h, only the heat engine operates. This is the normal operating way at the road.

(b) ICE + electric power: if more energy is needed (during acceleration or at high speed), the electric motor starts working in parallel to the heat engine, achieving greater power

(c) ICE + battery charging: if less power is required, excess of energy is used to charge the batteries. Operating the engine at higher torque than necessary, it runs at a higher efficiency.

(d) regenerative breaking: While braking or decelerating, the electric motor takes profit of the kinetic energy of the he moving vehicle to act as a generator.

Sometimes, an extra generator is used: then the batteries can be recharged when the vehicle is not driving, the ICE operates disconnected from the transmission. But this system gives an increased weight and price to the HEV.



A parallel HEV can have an extra generator for the battery (left)Without generator, the motor will charge the battery (right)

Weaknesses of parallel hybrid vehicles:

- Rather complicated system.
- The ICE doesn't operate in a narrow or constant RPM range, thus efficiency drops at lowrotation speed.
- As the ICE is not decoupled from the wheels, the battery cannot be charged at standstill.

Advantages of parallel hybrid vehicles:

- Total efficiency is higher during cruising and long-distance highway driving.
- Large flexibility to switch between electric and ICE power
- Compared to series hybrids, the electromotor can be designed less powerful than the ICE, as itis assisting traction. Only one electrical motor/generator is required.

Example of PHEV:

Honda Civic. Honda's IMA (Integrated Motor Assist) uses a rather traditional ICE with continuouslyvariable transmission, where the flywheel is replaced with an electric motor.

Influence of scale: a Volvo 26 ton truck (12 ton own weight, 14 ton max load) equipped with 200 kg of batteries can drive on pure electric power

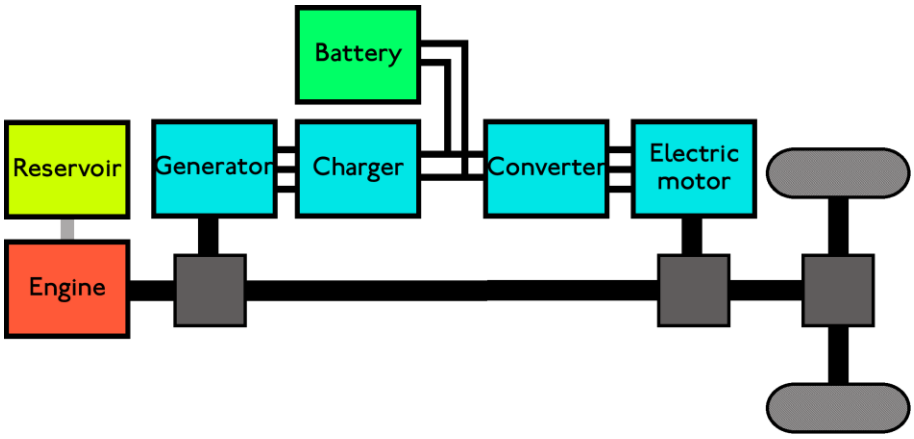
for 2 minutes only! Because of space constraints, it is not possible to build in more batteries.

BMW 7Series ActiveHybrid.

Combined hybrid

Combined hybrid systems have features of both series and parallel hybrids. There is a *double connection between the engine and the drive axle: mechanical and electrical*. This split power path allows interconnecting mechanical and electrical power, at some cost in complexity.

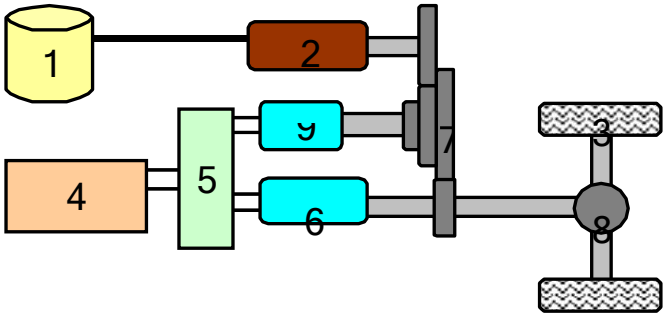
Power-split devices are incorporated in the powertrain. The power to the wheels can be either mechanical or electrical or both. This is also the case in parallel hybrids. But the main principle behind the combined system is the *decoupling of the power supplied by the engine from the power demanded by the driver*.



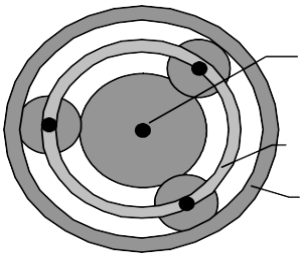
Simplified structure of a combined hybrid electric vehicle

In a conventional vehicle, a larger engine is used to provide acceleration from standstill than one needed for steady speed cruising. This is because a combustion engine's torque is minimal at lower RPMs, as the engine is its own air pump. On the other hand, an electric motor exhibits maximum torque at stall and is well suited to complement the engine's torque deficiency at low RPMs. In a combined hybrid, a smaller, less flexible, and highly efficient engine can be used. It is often a variation of the conventional Otto cycle, such as the Miller or Atkinson cycle. This contributes significantly to the higher overall efficiency of the vehicle, with regenerative braking playing a much smaller role.

At lower speeds, this system operates as a series HEV, while at high speeds, where the series powertrain is less efficient, the engine takes over. This system is more expensive than a pure parallel system as it needs an extra generator, a mechanical split power system and more computing power to control the dual system.



1: Fuel tank
2: Engine
3: Wheels
4: Battery
5: Convertors
6: MG2
7: Power Split device
8: Differential
9: MG1



S: sun

$$\omega_S + \rho \cdot \omega_C = \omega_R + \rho \cdot \omega_C$$

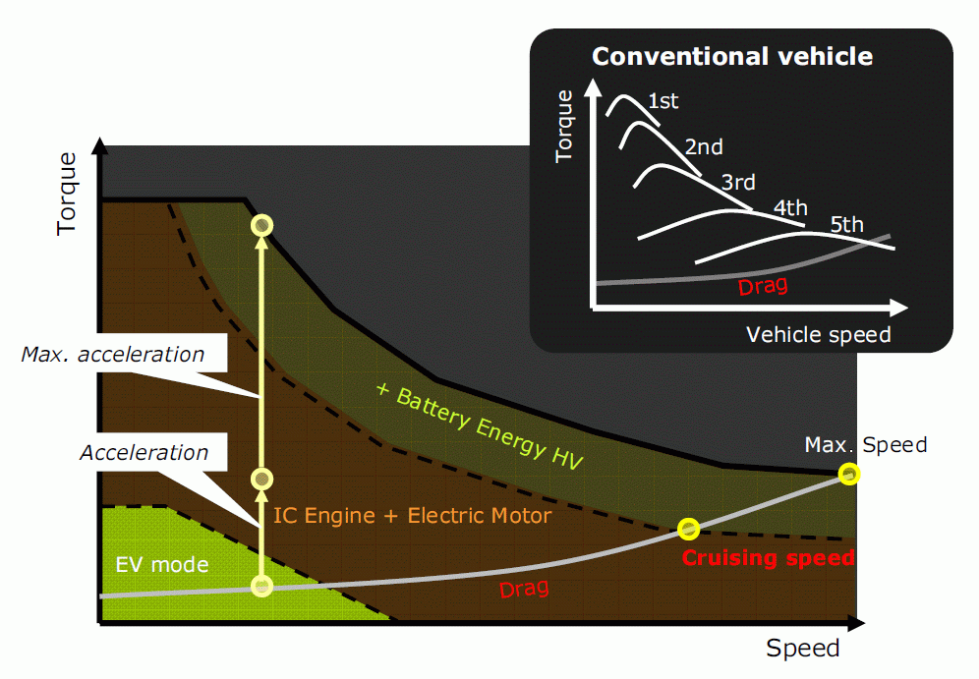
$$\rho = (1) \quad C \quad S \quad R$$

C: carrier

$$z_R / z_S$$

R: ring

Combined HEV with planetary unitas used in the Toyota Prius



Combined hybrid drive modes

Weaknesses of combined hybrid vehicles:

- Very complicated system, more expensive than parallel hybrid.
- The efficiency of the power train transmission is dependent on the amount of power being transmitted over the electrical path, as multiple conversions, each with their own efficiency, lead to a lower efficiency of that path (~70%) compared with the purely mechanical path (98%).

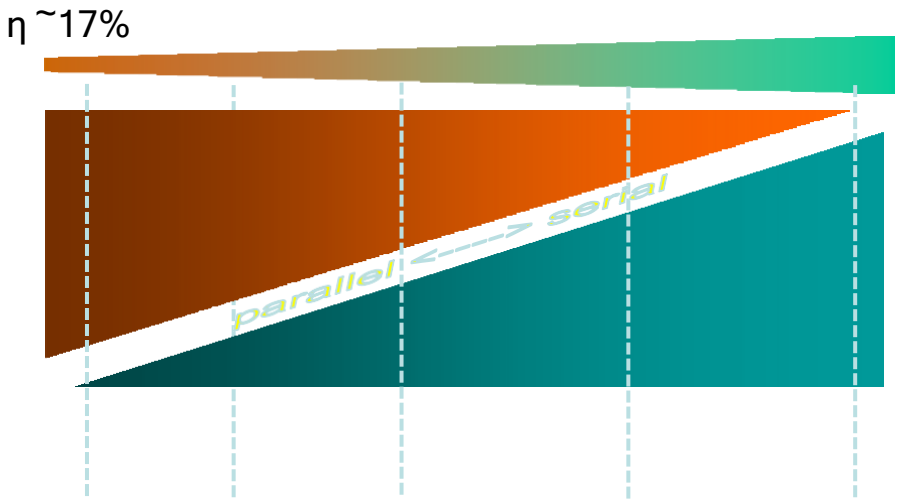
Advantages of combined hybrid vehicles:

- Maximum flexibility to switch between electric and ICE power
- Decoupling of the power supplied by the engine from the power demanded by the driver allows for a smaller, lighter, and more efficient ICE design.

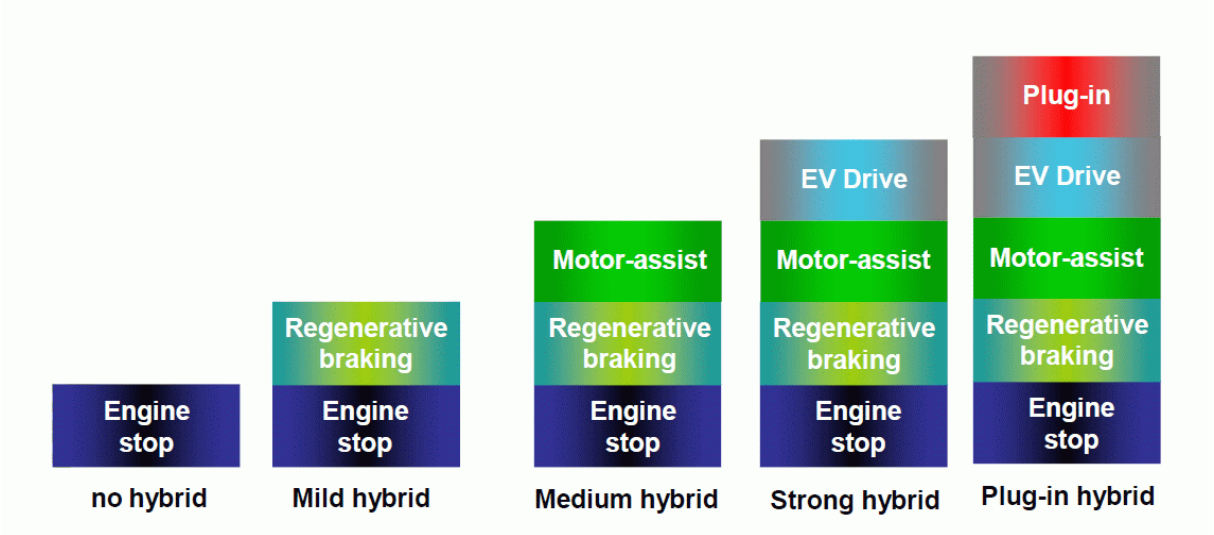
Example of CHEV: Toyota Prius, Auris, Lexus CT200h, Lexus RX400h.

2. Types by degree of hybridization

Parallel and combined hybrids can be categorized depending upon how balanced the different portions are at providing motive power. In some cases, the combustion engine is the dominant portion; the electric motor turns on only when a boost is needed. Others can run with just the electric system operating.



Con-ventional	Micro-HEV	Medium/ mild-HEV	Full-HEV	Plug-In HEV	Electric Vehicle
Vehicle	e.g. BMW 1er „Stop& Start“	e.g. Citroen C4 HDi	e.g. Toyota Prius, Auris	e.g. Volvo C30 Concept	



Overview of Hybrid-powertrain concepts

Strong hybrid (= full hybrid)

A full hybrid EV can run on just the engine, just the batteries, or a combination of both. A large, high-capacity battery pack is needed for battery-only operation.

Examples:

The Toyota Prius, Auris and Lexus are full hybrids, as these cars can be moved forward on battery power alone. The Toyota brand name for this technology is Hybrid Synergy Drive. A computer oversees operation of the entire system, determining if engine or motor, or both should be running. The ICE will be shut off when the electric motor is sufficient to provide the power.

Medium hybrid (= motor assist hybrid)

Motor assist hybrids use the engine for primary power, with a torque-boosting electric motor connected in *parallel* to a largely conventional powertrain. EV mode is only possible for a very limited period of time, and this is not a standard mode. Compared to full hybrids, the amount of electrical power needed is smaller, thus the size of the battery system can be reduced. The electric motor, mounted between the engine and transmission, is essentially a very large starter motor, which operates

not only when the engine needs to be turned over, but also when the driver "steps on the gas" and requires extra power. The electric motor may also be used to re-start the combustion engine, deriving the same benefits from shutting down the main engine at idle, while the enhanced battery system is used to power accessories. The electric motor is a generator during regenerative breaking.

Examples:

Honda's hybrids including the Civic and the Insight use this design, leveraging their reputation for design of small, efficient gasoline engines; their system is dubbed Integrated Motor Assist (IMA). Starting with the 2006 Civic Hybrid, the IMA system now can propel the vehicle solely on electric power during medium speed cruising.

A variation on this type of hybrid is the Saturn VUE Green Line hybrid system that uses a smaller electric motor (mounted to the side of the engine), and battery pack than the Honda IMA, but functions similarly.

Another variation on this type is Mazda's e-4WD system, offered on the Mazda Demio sold in Japan. This front-wheel drive vehicle has an electric motor which can drive the rear wheels when extra traction is needed. The system is entirely disengaged in all other driving conditions, so it does not enhance performance or economy.

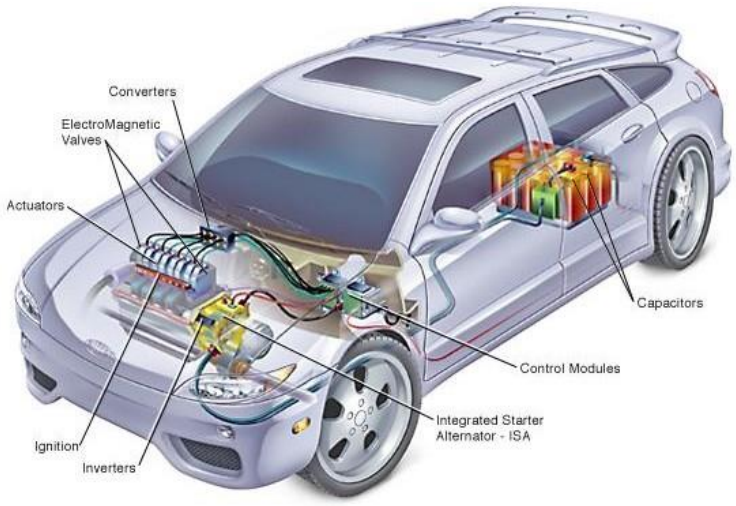
Mild hybrid / micro hybrid (= start/stop systems with energy recuperation)

Mild hybrids are essentially conventional vehicles with oversized starter motors, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly.
During restart, the larger motor is used to spin up the engine to operating rpm speeds before injecting any fuel. That concept is not unique to hybrids; Subaru pioneered this feature in the early 1980s, and the Volkswagen Lupo 3L is one example of a conventional vehicle that shuts off its engine when at a stop.

As in other hybrid designs, the motor is used for regenerative braking to recapture energy. But there is no motor-assist, and no EV mode at all. Therefore, many people do not consider these to be hybrids, since there is no electric motor to drive the vehicle, and these vehicles do not achieve the fuel economy of real hybrid models.

Some provision must be made for accessories such as air conditioning which are normally driven by the engine. Those accessories can continue to run on electrical power while the engine is off.

Furthermore, the lubrication systems of internal combustion engines are inherently least effective immediately after the engine starts; since it is upon startup that the majority of engine wear occurs, the frequent starting and stopping of such systems reduce the lifespan of the engine considerably. Also, start and stop cycles may reduce the engine's ability to operate at its optimum temperature, thus reducing the engine's efficiency.



Powertrain of a mild HEV

Examples:

BMW succeeded in combining regenerative braking with the mild hybrid "start-stop" system in their current 1-series model.

Citroën proposes a start-stop system on its C2 and C3 models. The concept-car C5 Airscape has an improved version of that, adding regenerative breaking and traction assistance functionalities, and supercapacitors for energy buffering.

Plug-in hybrid (= grid connected hybrid = vehicle to grid V2G)

All the previous hybrid architectures could be grouped within a classification of *charge sustaining*: the energy storage system in these vehicles is designed to remain within a fairly confined region of state of charge (SOC). The hybrid propulsion algorithm is designed so that on average, the SOC of energy storage system will more or less return to its initial condition after a drive cycle.

A plug-in hybrid electric vehicle (PHEV) is a *full hybrid*, able to run in electric-only mode, with larger batteries and the ability to recharge from the electric power grid. Their main benefit is that they can be gasoline-

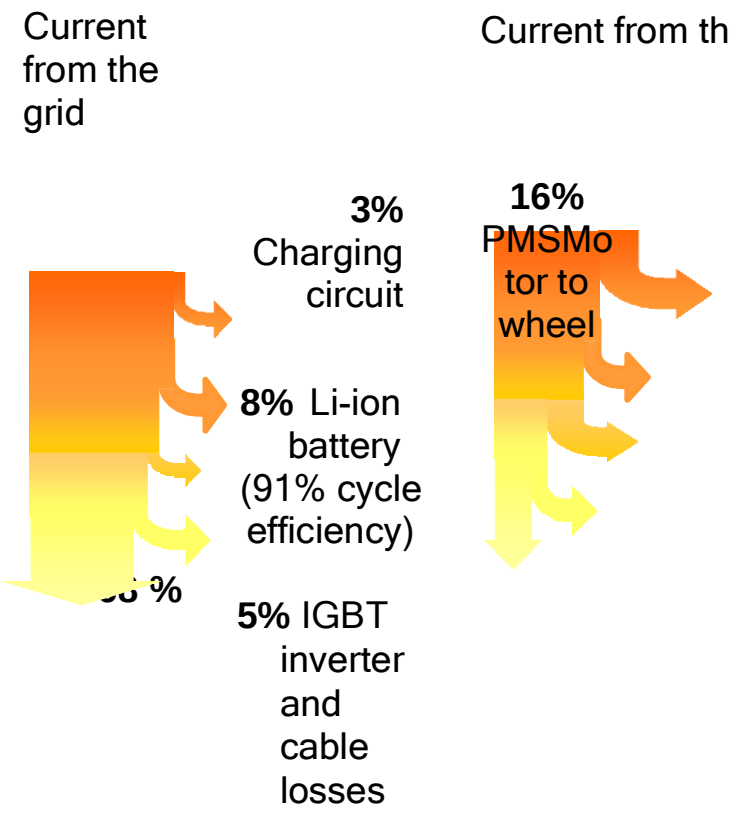
independent for daily commuting, but also have the extended range of a hybrid for long trips.

Grid connected hybrids can be designed as *charge depleting*: part of the “fuel” consumed during a drive is delivered by the utility, by preference at night. Fuel efficiency is then calculated based on actual fuel consumed by the ICE and its gasoline equivalent of the kWh of energy delivered by the utility during recharge. The "well-to-wheel" efficiency and emissions of PHEVs compared to gasoline hybrids depends on the energy sources used for the grid utility (coal, oil, natural gas, hydroelectric power, solar power, wind power, nuclear power).

In a serial Plug-In hybrid, the ICE only serves for supplying the electrical power via a coupled generator in case of longer driving distances. Plug in hybrids can be made multi-fuel, with the electric power supplemented by diesel, biodiesel, or hydrogen.

The Electric Power Research Institute's research indicates a lower total cost of ownership for PHEVs due to reduced service costs and gradually improving batteries.

Some scientists believe that PHEVs will soon become standard in the automobile industry. Plug-in vehicles which use batteries to store electric energy *outperform* cars which use hydrogen as carrier for the energy taken from the grid. The following figures indicate the efficiencies of a hydrogen fuel cell HEV and a battery powered EV.



Traction power efficiency of a plugged EV.
Left a battery powered plug in EV (Mitsubishi Lancer Evolution MIEV)) Right a Fuel Cell EV (Mercedes NECAR 3)

For typical driving cycles, the achieved efficiencies are lower. The battery powered EV achieves efficiencies in the range of 50 to 60%. The hydrogen powered EV has a total efficiency of about 13% only at those drive cycles.

Examples:

Mercedes BlueZERO E-CELL PLUS (concept car): series HEV. Opel Ampera: series

HEV.

Plug-in-Hybrid Opel Ampera

The Plug-in-Hybrid Volvo C30 (concept car) is a series HEV. It has a 1,6 liter gasoline/bio-ethanol ICE. A synchronous generator charges the Li-polymer battery (ca. 100 km autonomy) when the battery SoC is lower

than 30%. There are four electric wheel-motors.

Plug-in-Hybrid Volvo C30

3. Types by nature of the power source

Electric-internal combustion engine hybrid

There are many ways to create an electric-internal combustion hybrid. The variety of electric-ICE designs can be

differentiated by how the electric and combustion portions of the powertrain connect (series, parallel or combined), at what times each portion is in operation, and what percent of the power is provided by each hybrid component. Many designs shut off the internal combustion engine when it is not needed in order to save energy, see 2.3.

Fuel cell hybrid

Fuel cell vehicles have a series hybrid configuration. They are often fitted with a battery or supercapacitor to deliver peak acceleration power and to reduce the size and power constraints on the fuel cell (and thus its cost). See 1.1.

Human power and environmental power hybrids

Many land and water vehicles use human power combined with a further power source. Common are parallel hybrids, e.g. a boat being rowed and also having a sail set, or motorized bicycles. Also some series hybrids exist. Such vehicles can be tribrid vehicles, combining at the same time three power sources e.g. from on-board solar cells, from grid-charged batteries, and from pedals.

The following examples don't use electrical power, but can be considered as hybrids as well:

Pneumatic hybrid

Compressed air can also power a hybrid car with a gasoline compressor to provide the power. Moteur Developpement International in France produces such air cars. A team led by Tsu-Chin Tsao, a UCLA mechanical and aerospace engineering professor, is collaborating with engineers from Ford to get Pneumatic hybrid technology up and running. The system is similar to that of a hybrid-electric vehicle in that braking energy is harnessed and stored to assist the engine as needed during acceleration.

Hydraulic hybrid

A hydraulic hybrid vehicle uses hydraulic and mechanical components instead of electrical ones. A variable displacement pump replaces the motor/generator, and a hydraulic accumulator (which stores energy as highly

compressed nitrogen gas) replaces the batteries. The hydraulic accumulator, which is essentially a pressure tank, is potentially cheaper and more durable than batteries. Hydraulic hybrid technology was originally developed by Volvo Flygmotor and was used experimentally in buses from the early 1980s and is still an active area.

Initial concept involved a giant flywheel (see Gyrobus) for storage connected to a hydrostatic transmission, but it was later changed to a simpler system using a hydraulic accumulator connected to a hydraulic pump/motor. It is also being actively developed by Eaton and several other companies, primarily in heavy vehicles like buses, trucks and military vehicles. An example is the Ford F-350 Mighty Tonka concept truck shown in 2002. It features an Eaton system that can accelerate the truck up to highway speeds.