DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

ON

AUTOMOBILE ENGINEERING & HYBRID VEHICLES

by

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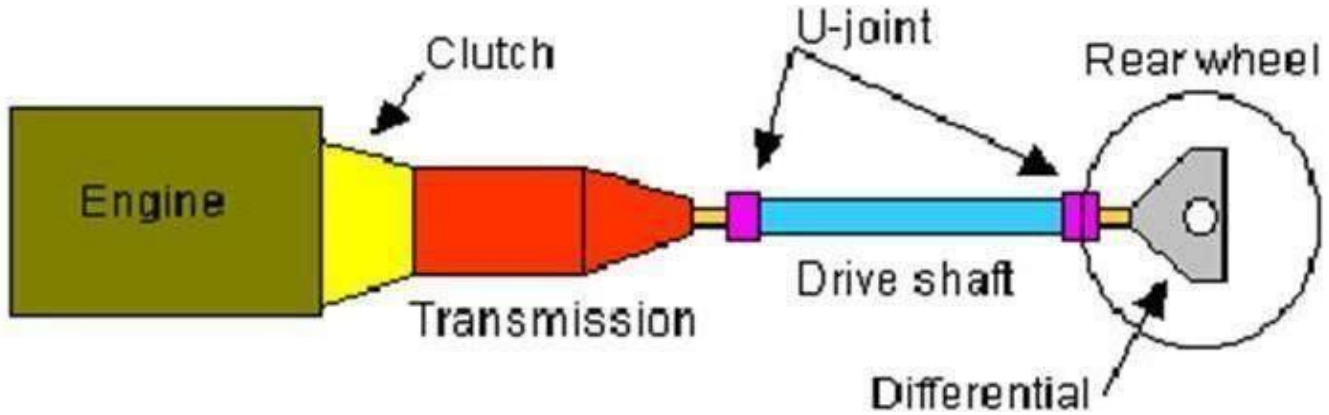
What is Automobile

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

Components of Automobile

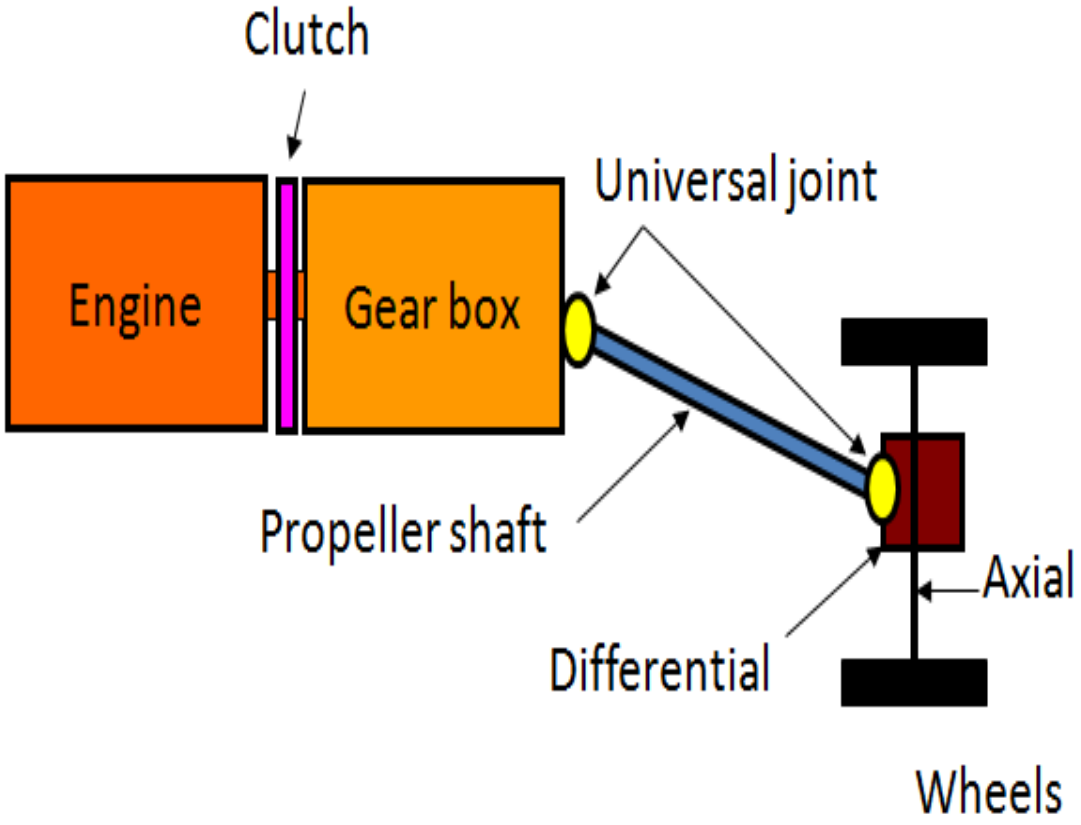
- Basic Structure
- Power plant
- Transmission system
- Auxiliaries
- Controls
- Super structure



Transfer power from engine to wheels

TRANSMISSION

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



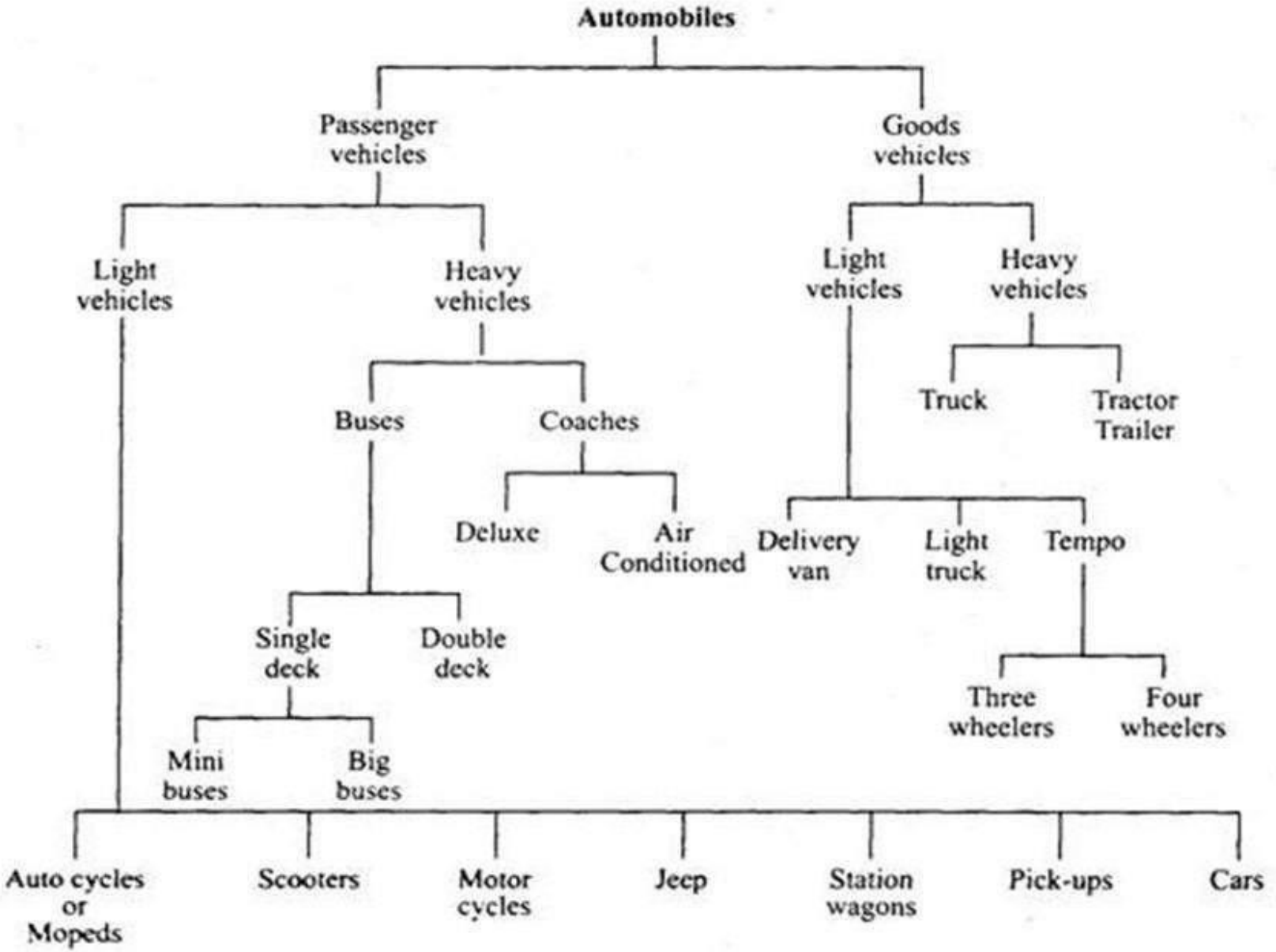
POWER TRAIN

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:

- heavytransport vehicles(H.T.V)liketruck&buses.
- Lighttransport vehicles(L.T.V)likecars,jeepsetc.

3. Fuel used:

- petrolvehicles
- Dieselvehicles
- Gasvehicles
- Electricvehicle

4. wheels:

- Twowheelerslikescooters,motorcyclesetc.
- Threewheelerslikeautorickshwas,tempo.
- Fourwheelerslikecars,jeeps.
- Sixwheelersliketrucks,bus.

5. Body style:

- Closedcarslike:saloon,coupeetc.
- Opencarslikesportscar,convertiblecar.
- Specialstylesuchasestatecar,stationwagonetc.

6. Drive:

- Lefthanddrivee.g.vehiclesuseinU.S.A
- Righthandvehiclee.g.Indianvehicles.
- Frontwheeldrive
- Rearwheeldrive
- Allwheeldrive

7. Transmission:

- Manual
- Semi automatic
- Fullyautomatic

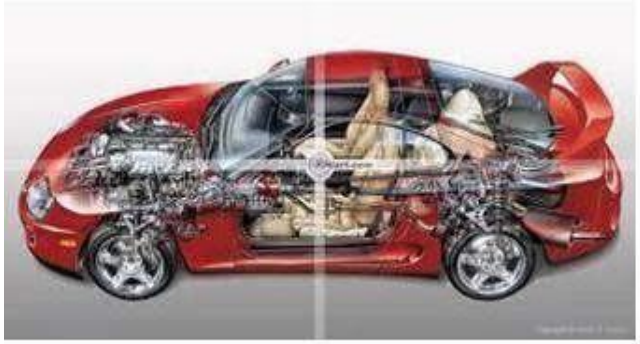
8. Suspension:

- Conventional:Leafspring

- Independent:Coilsprings,Pneumatic.

9. Position of engin

- Engine in front



- Engine in side driver's cabin

- 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 orwhere 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
  - Gearbox
  - 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.

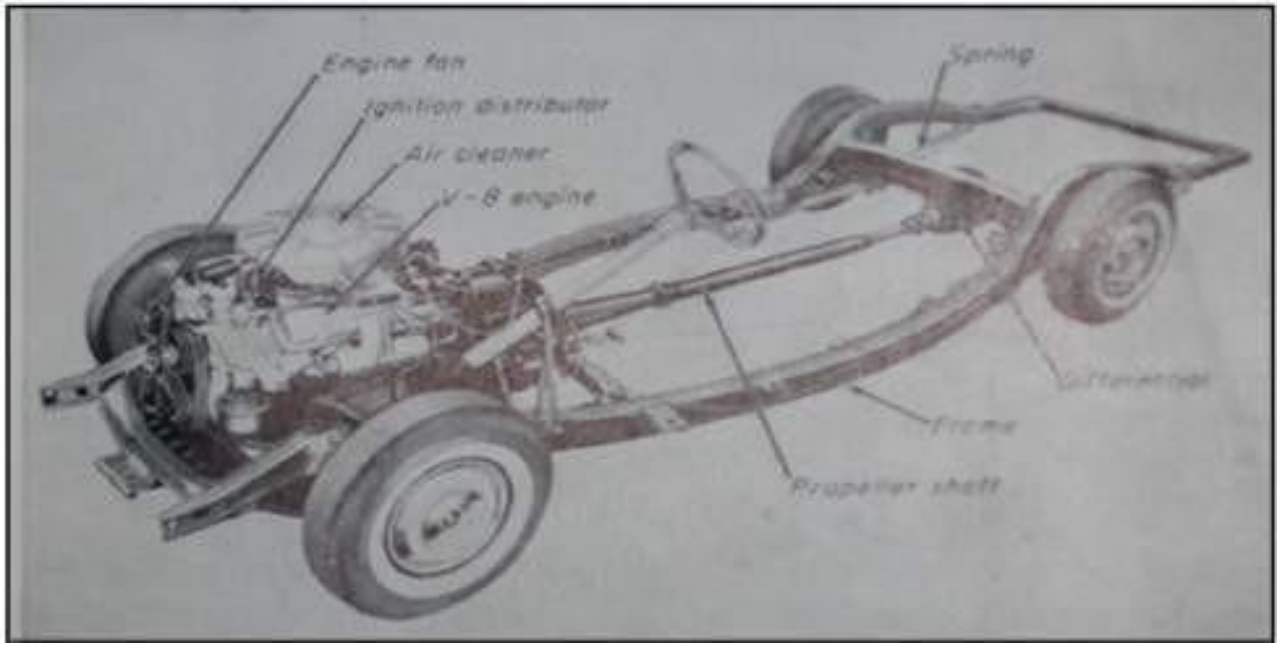
- The chassis of an automobile consists of the following components suitably mounted:

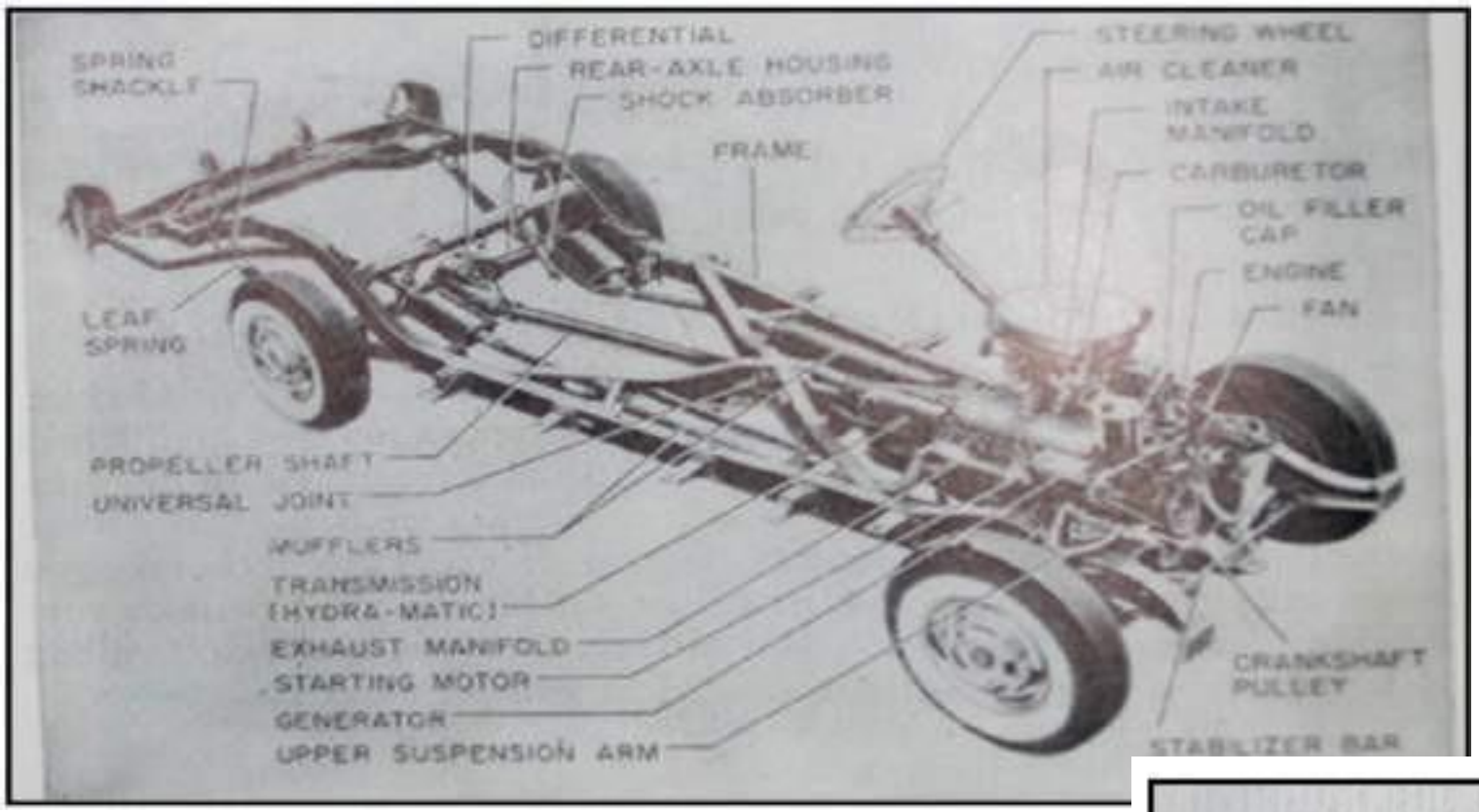
  (i) Frame (ii) Front axle (iii) Steering system (iv) Rear-axle (v) Suspension system (vi) Transmission (vii) Brake system (viii) Engine (ix) Electrical system. The chassis is sub-divided into (i) Power plant (ii) Running gear.

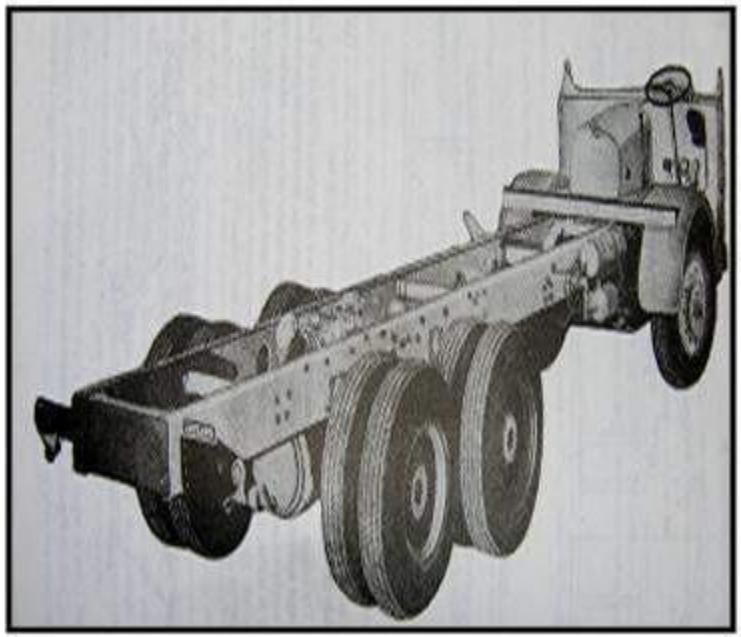
Chassis

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

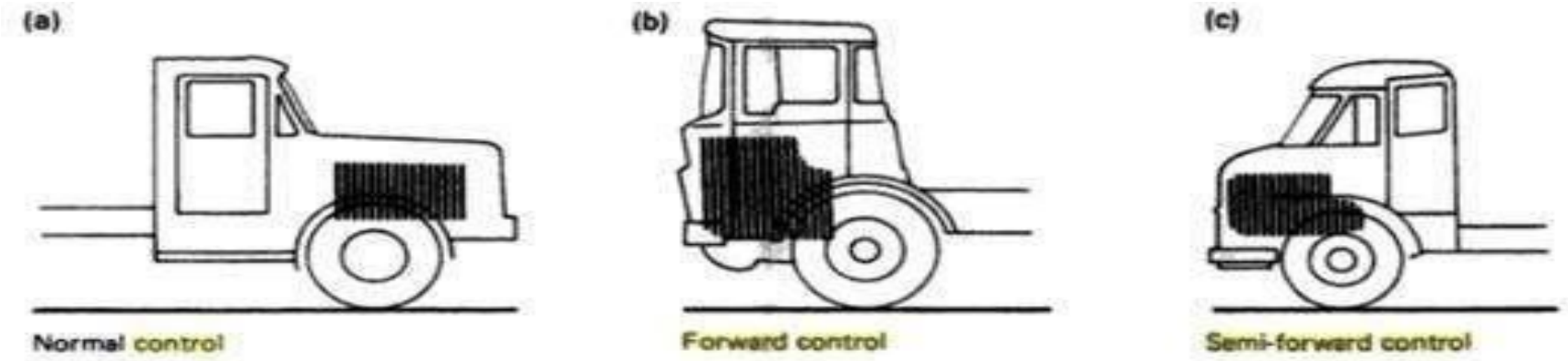


Chassis Classification

(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 Taba 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

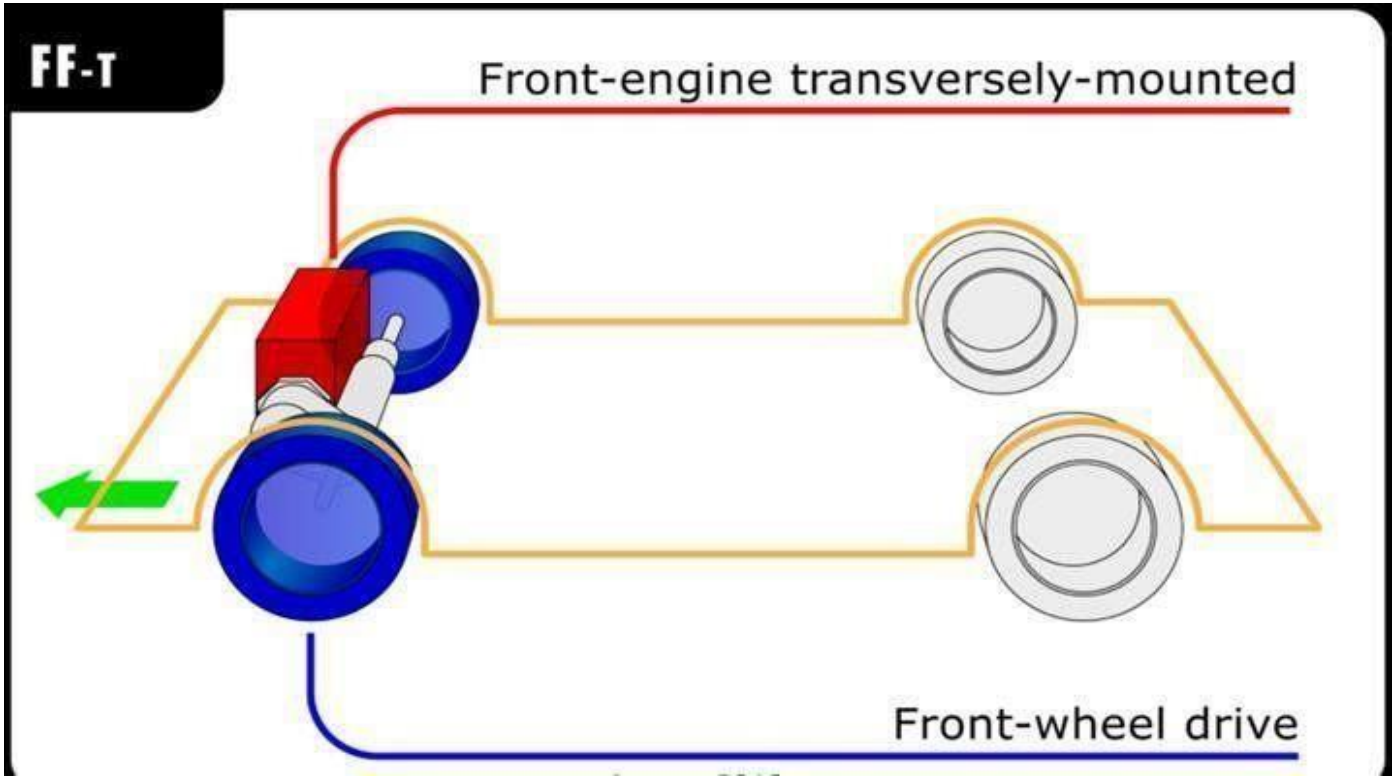
(ii) Engine fitted in front but crosswise

(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 drive shaft 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, oily surfaces.

Disadvantages of Front Wheel Drive

- Nose heavy (more weight distribution forward): which makes them prone to under steer 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

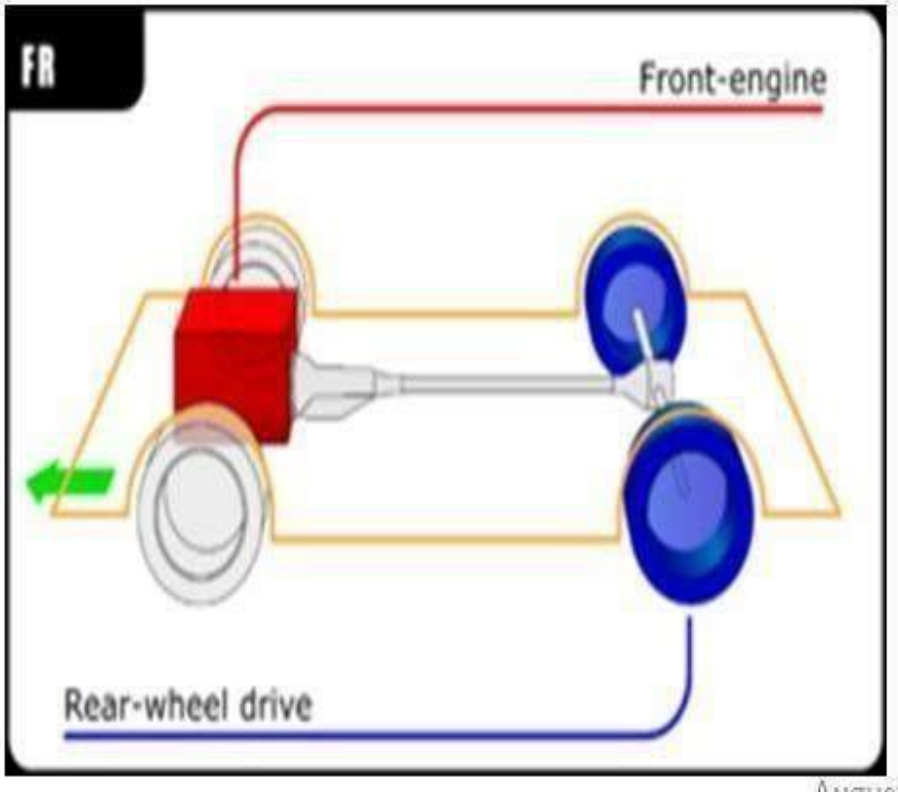
HYUNDAI i10 iRDE

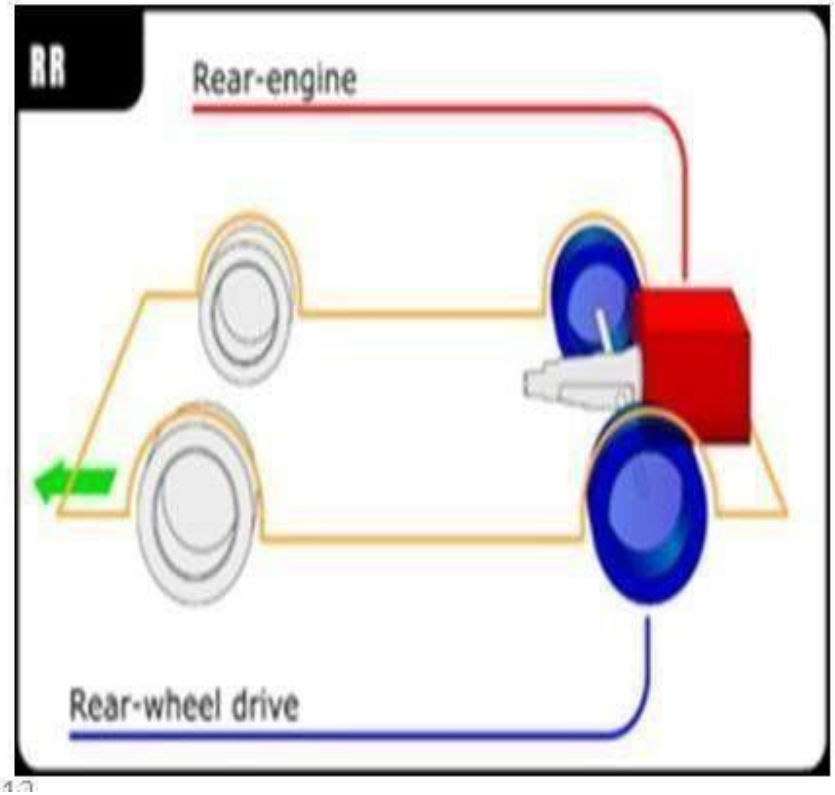
Engine 1086cc, 67PS, 98Nm
Transmission Five-speed manual, front-wheel drive
Performance 15.5 secs 0-100km/h,
Fuel efficiency 14.9kmpl (overall)

intelligent responsive drive engine

Rear Wheel Drive Layout

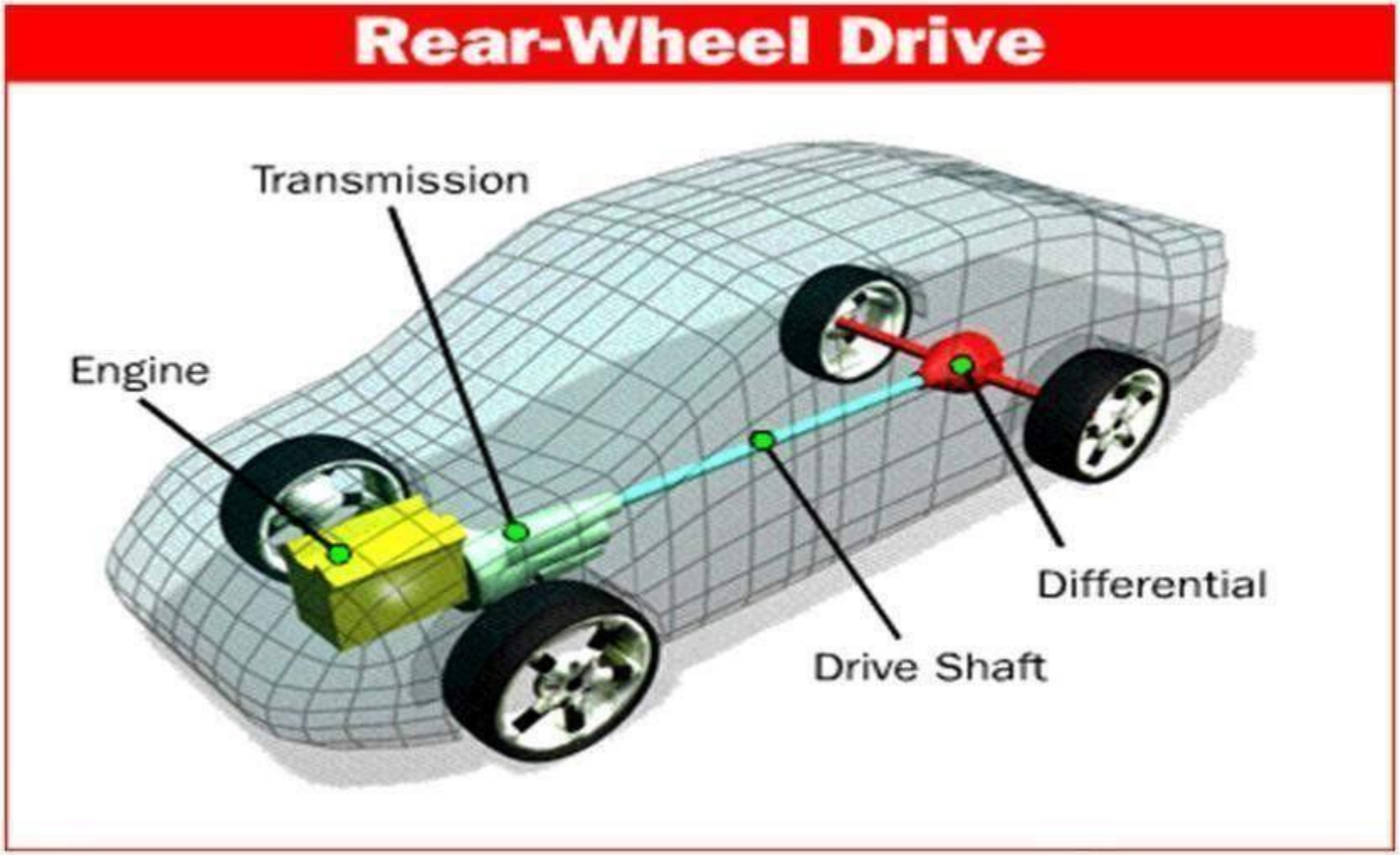
- Rear wheel drive typically places the engine in the front of the vehicle and the driven wheels are located at the rear a configuration known as front engine, rear wheel drive layout (FR layout).





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 drive train, such as the Inline-6, 90° big-bore V8, V10 and V12 making the FR a common configuration for luxury and sports cars.

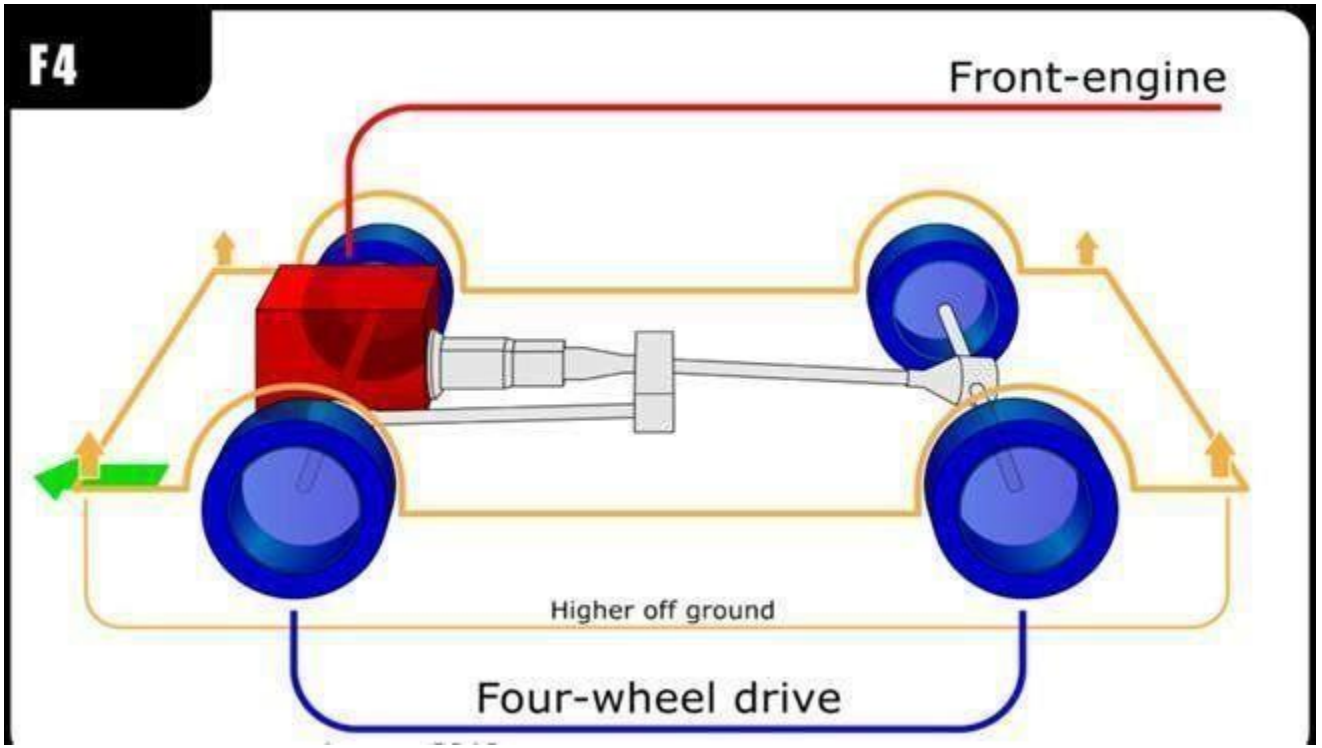
Disadvantages of Rear Wheel Drive Layout

- 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 drive train (approximately 17% losses between engine fly wheel 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)

- Most4WDlayoutarefrontenginedandarederivatives 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.

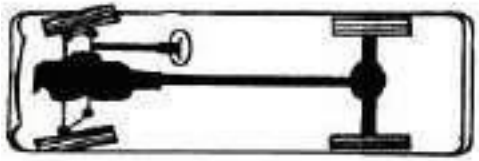


Fig. Conventional drive.

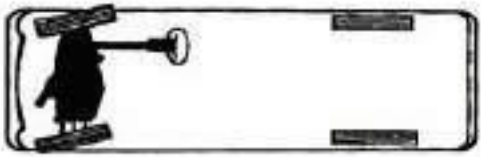


Fig. Front engine drive.

Fig. Centre engine drive.

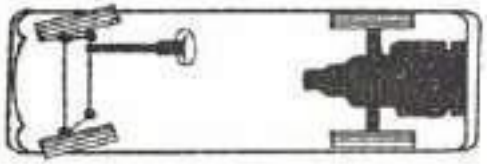


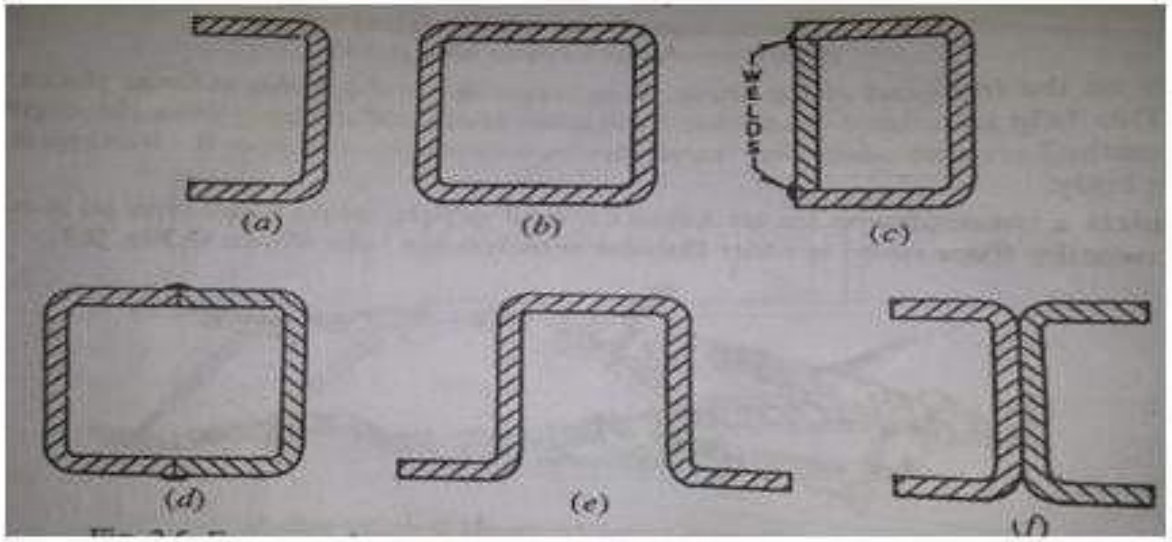
Fig. Rear engine drive.

Frame

- Function of the frame:

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

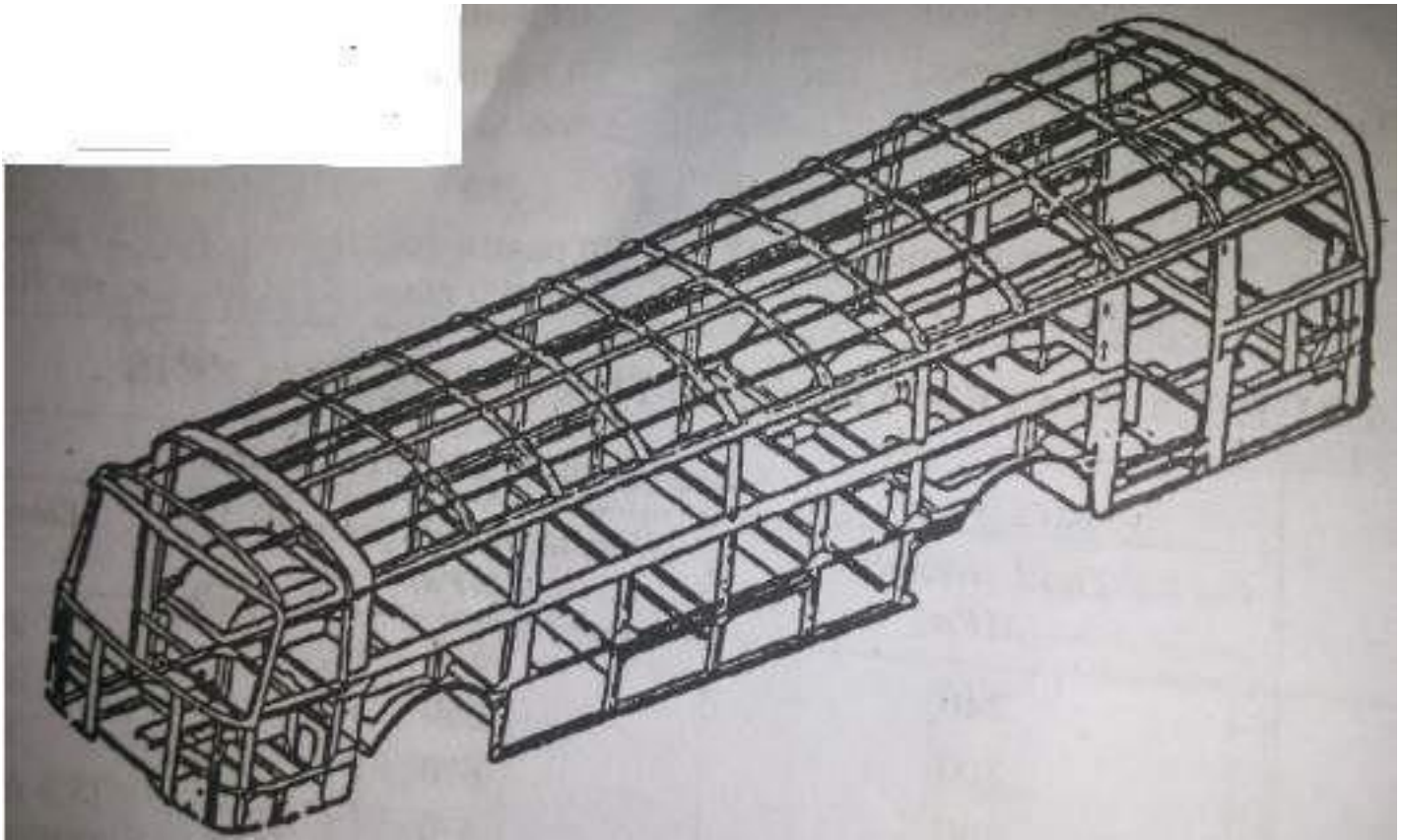
Frame sections



(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.

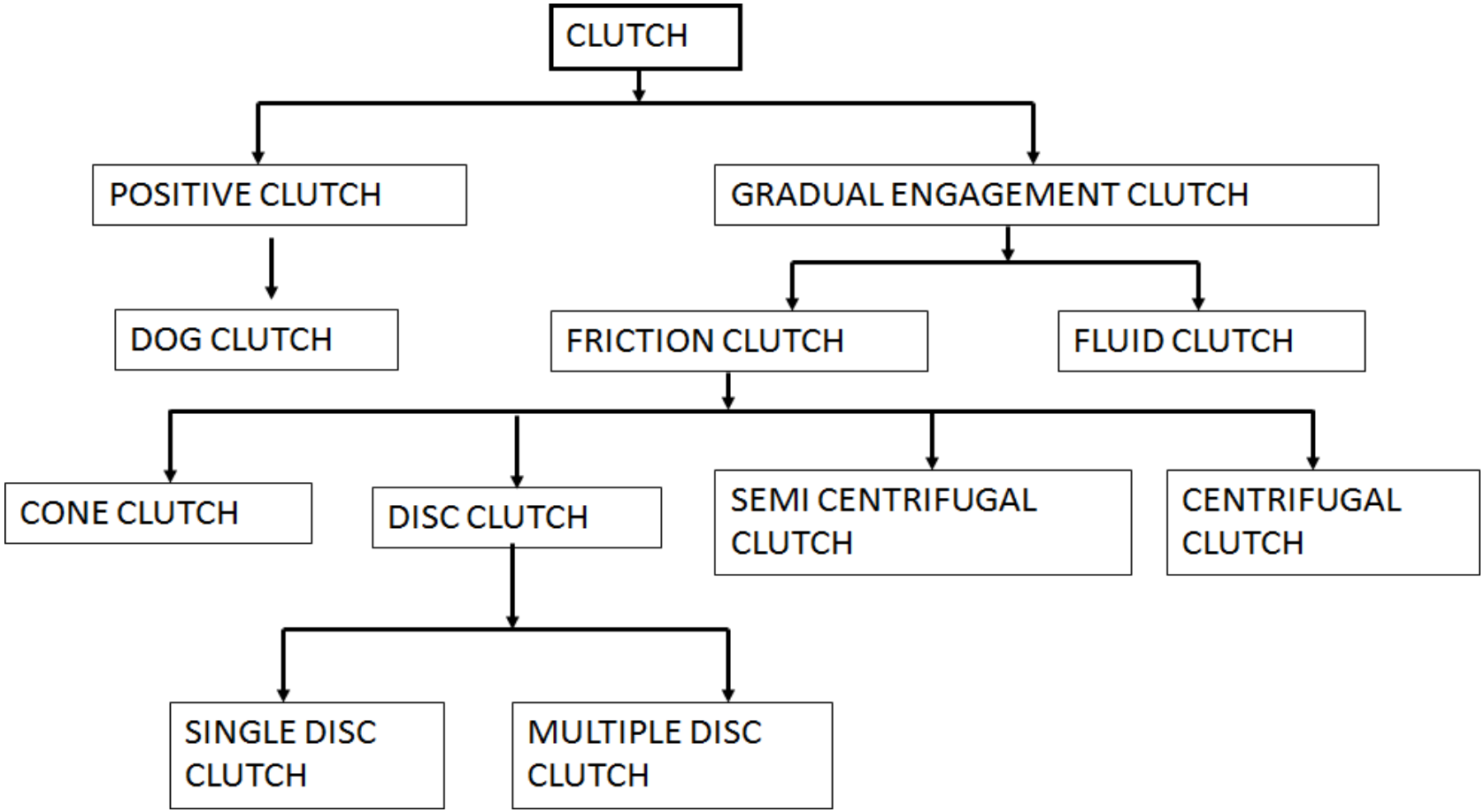
Requirements of Clutch

- 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

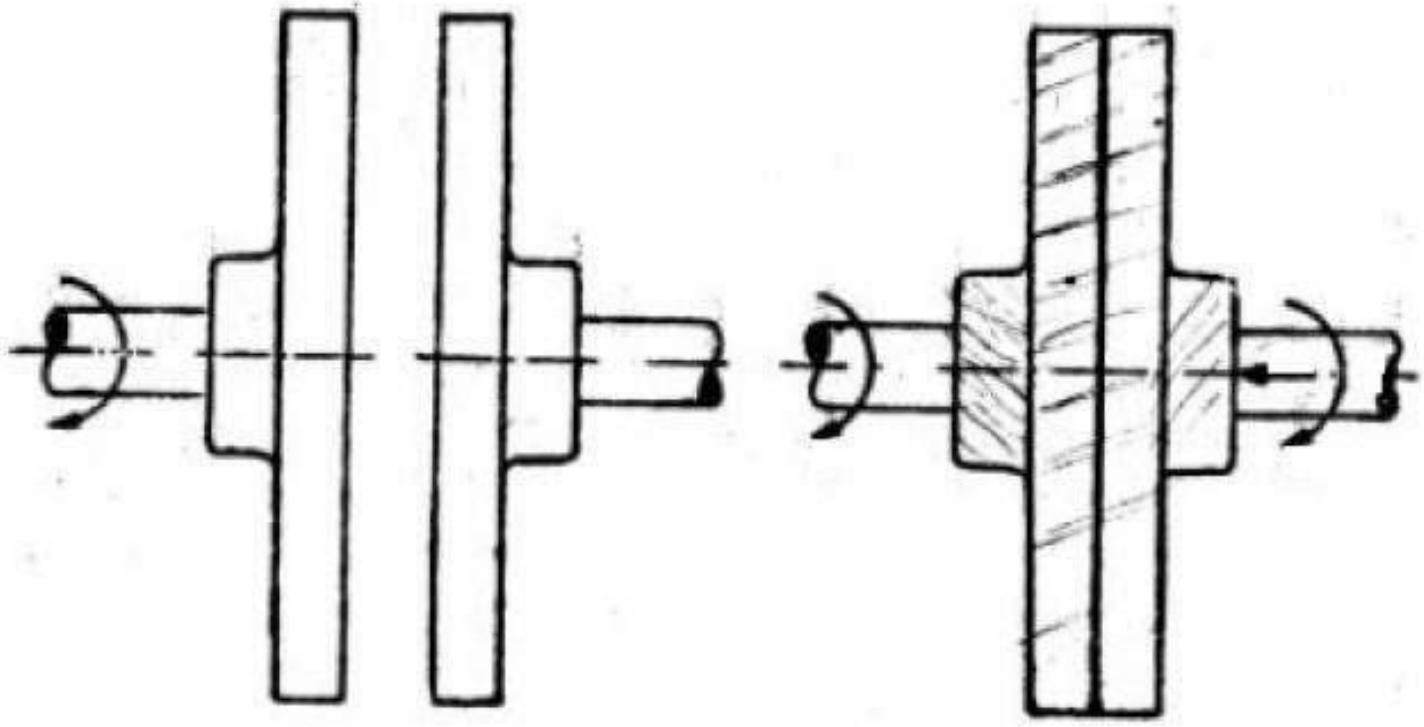
- FRICTION CLUTCHES: Enable the driven member to be disengaged and engaged gradually with the driving member.
- Action depends on the friction force between the members.
- At start low frictional force and increases with the pressing force.
- Pressure exerted by means of coil springs.

• 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 in to 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 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) Multi plate clutch

d) Semi centrifugal clutch

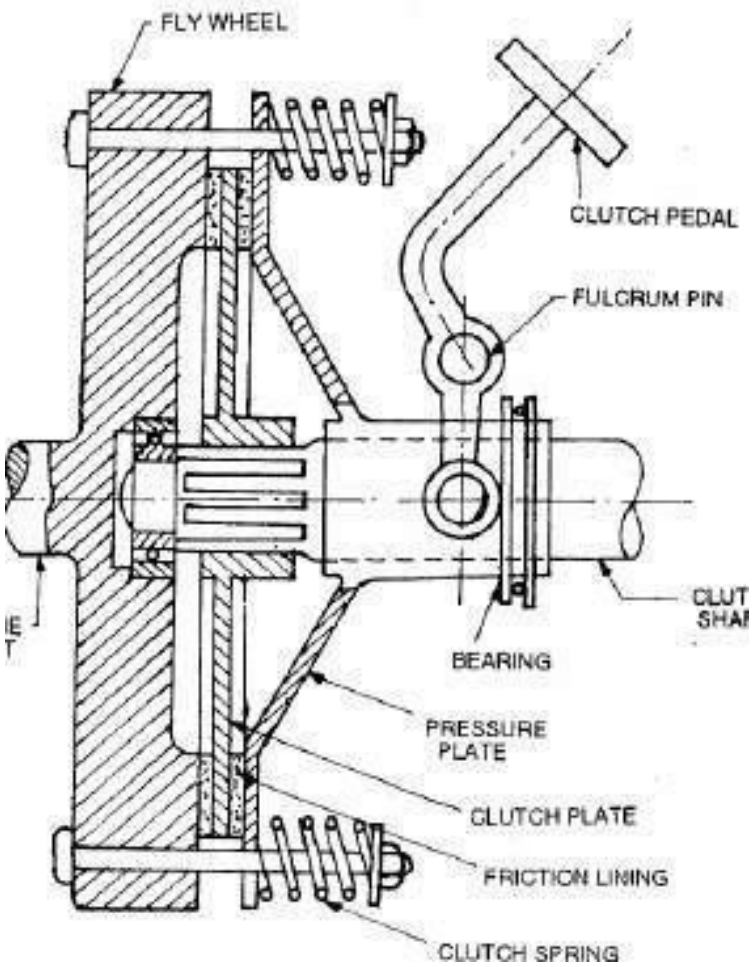
e) Centrifugal clutch.

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

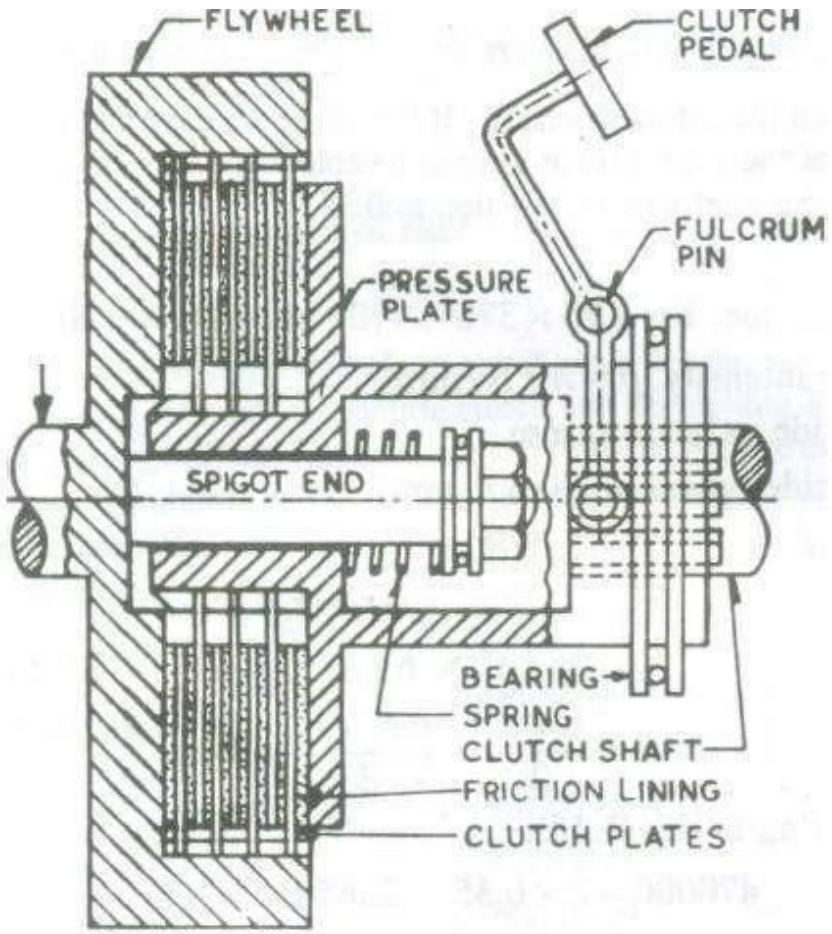
COIL-SPRING CLUTCH

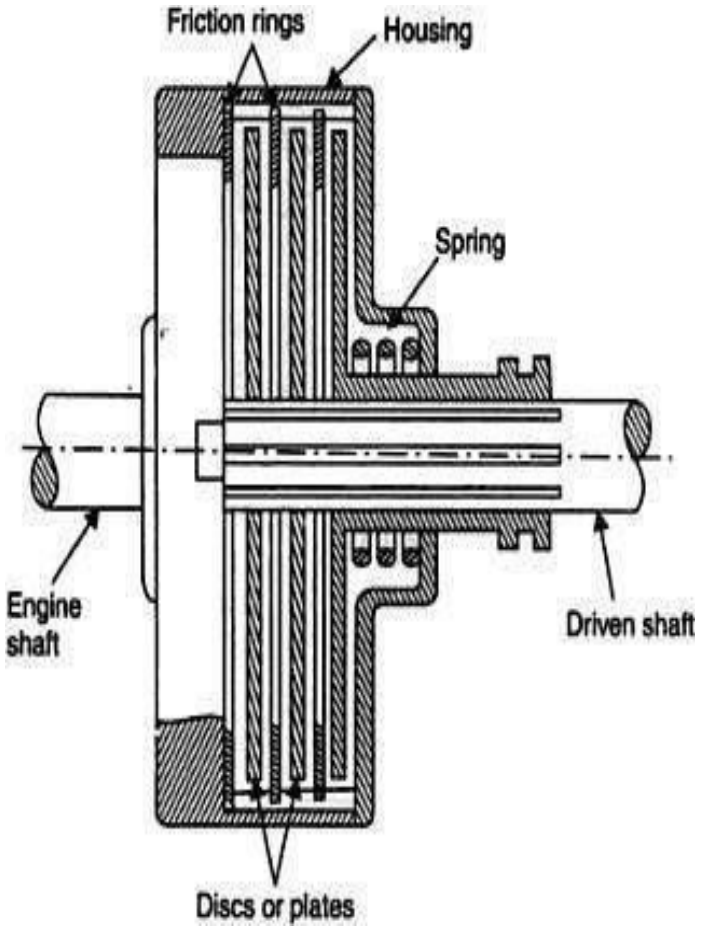


Construction and Working of Multi plate Clutch

- 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 fly wheel 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.

ConstructionandWorkingofMultiplateClutch

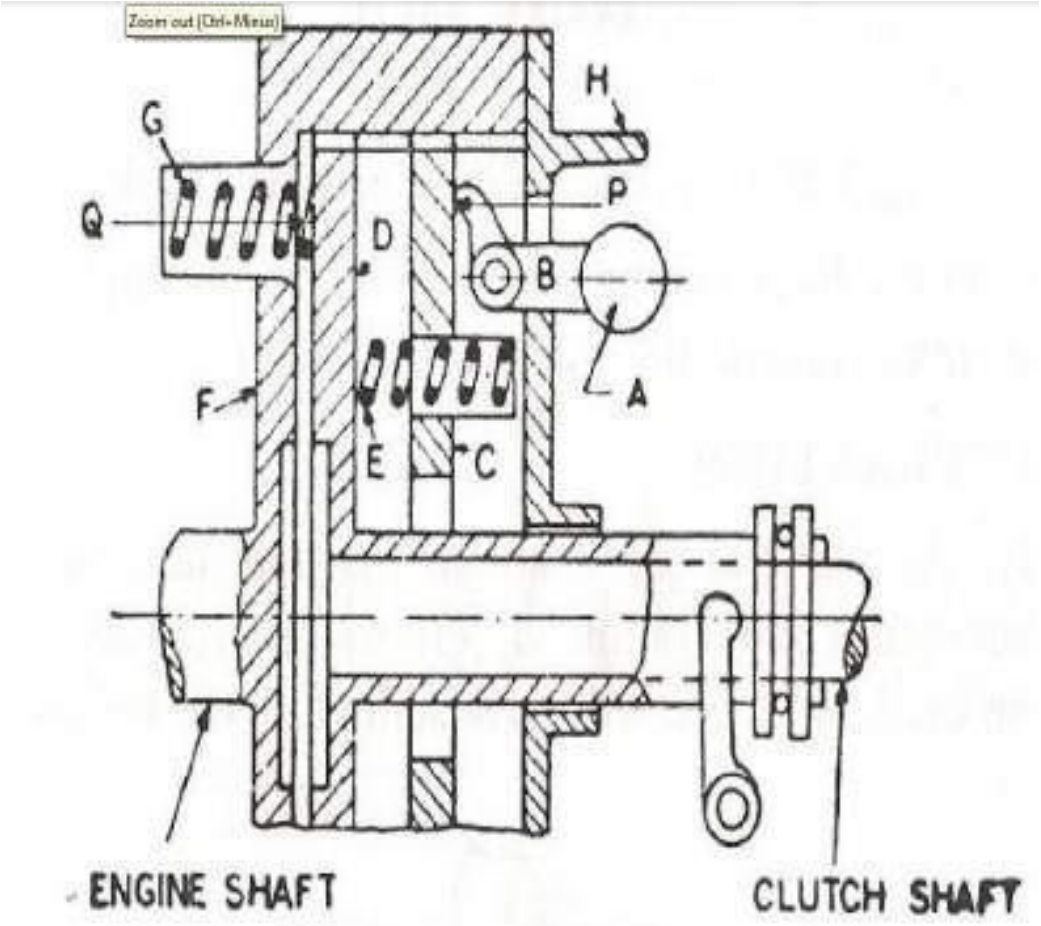




Centrifugal Clutch

- 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 about500r.p.m).The stop ‘H’ limits the amount of centrifugal force.

Centrifugal Clutch



Cone Clutch

- In this type the contact surfaces are in the formof cones as shown in the figure.
- In the engaged position, the male cone is fully inside the female conesothatthefrictionsurfacesareincompletecontact.
- Thisisdonebymeansofspringswhichkeepthe maleconepressed 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**

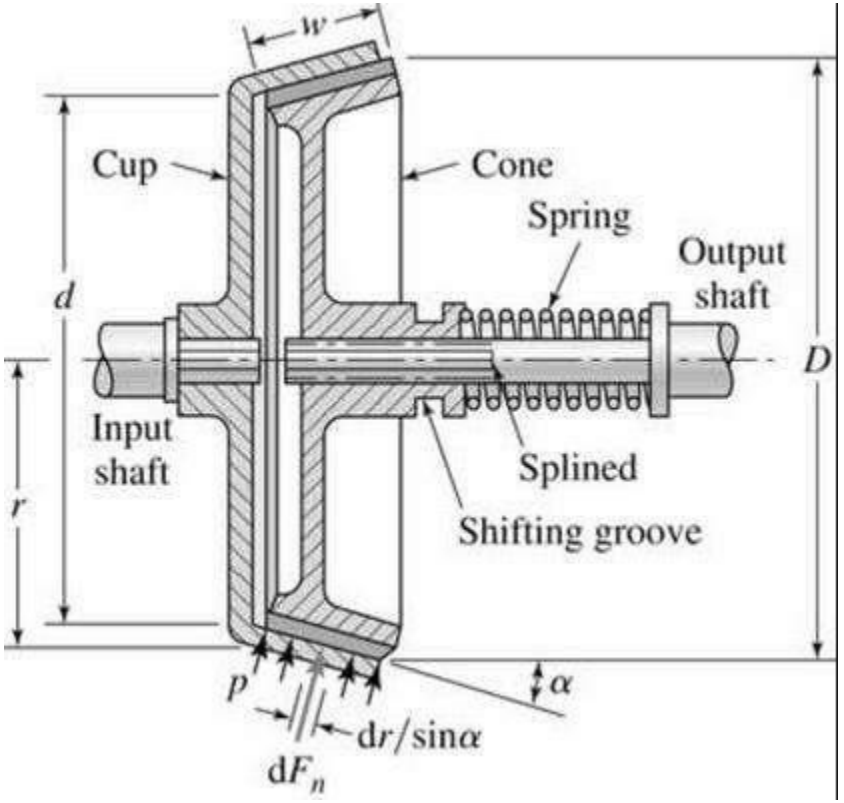
- The only advantage of the cone clutch is that the normal force acting on the contact surfaces in this case is larger than the axial force, as compared to the simple single plate clutch in which the normal force acting on the contact surfaces is equal to the axial force.

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 theclutch.
- 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

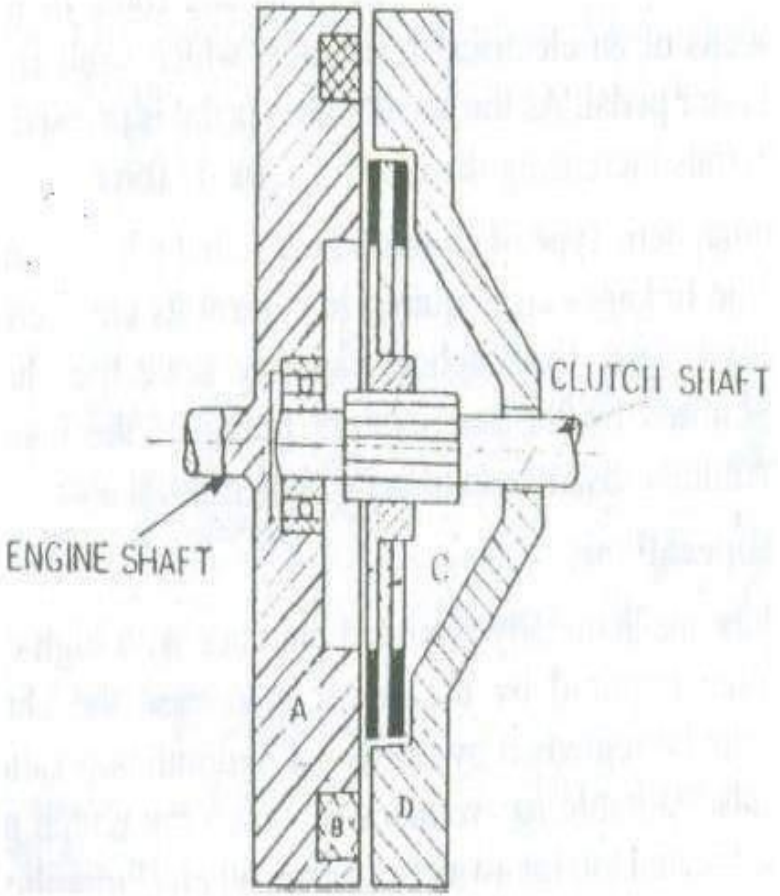


Electromagnetic Clutches

- 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’, there by engaging the clutch.
- When supply to winding ‘B’ is cutoff, 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.

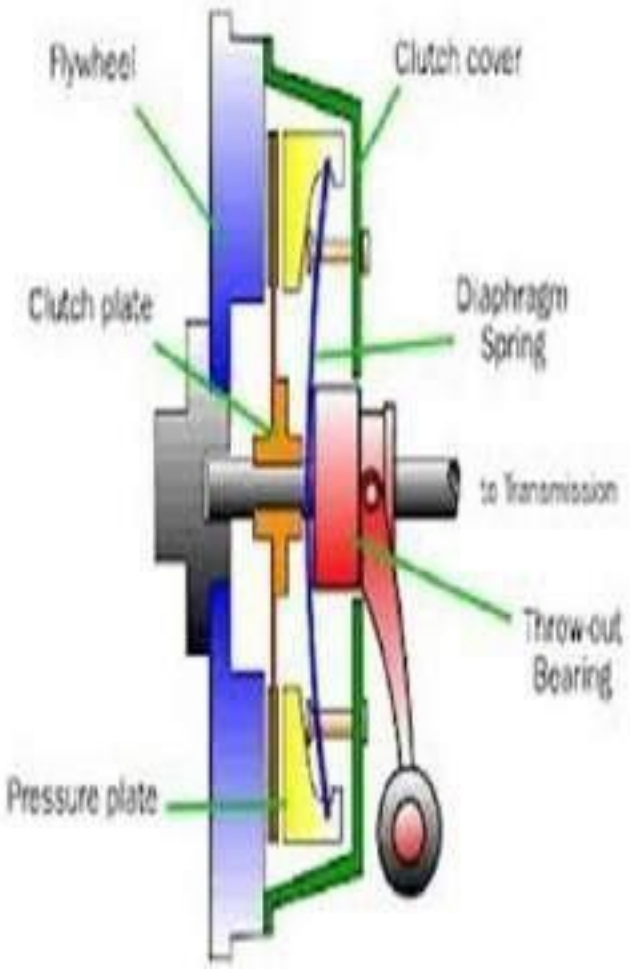
Electromagnetic Clutches

- 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.



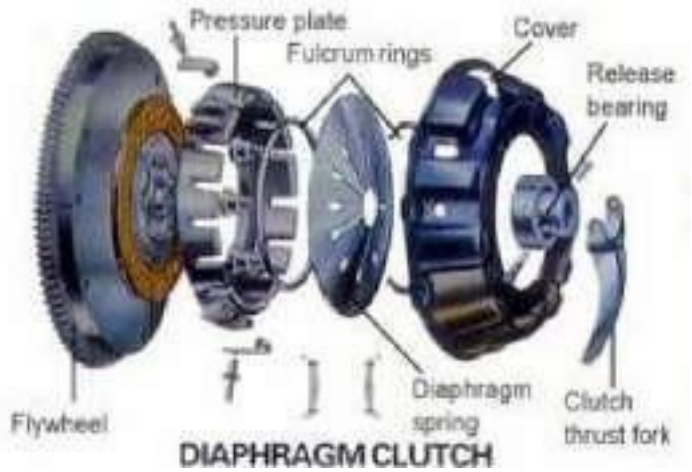
DiaphragmSpringClutch

- Diaphragmspringpressureplateassemblies are widely used in most modern cars.
- Thediaphragmspringisasinglethinsheetofmetal which yields when pressure is applied to it.
- Whenpressureisremovedthemetalsprings 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

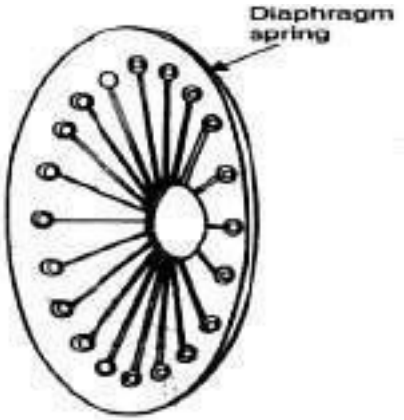


so that the clutch plate is engaged to the flywheel.

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 surface sfrom slipping.
- Today's clutch linings are usually made from fiber glass, kevlaror 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 :

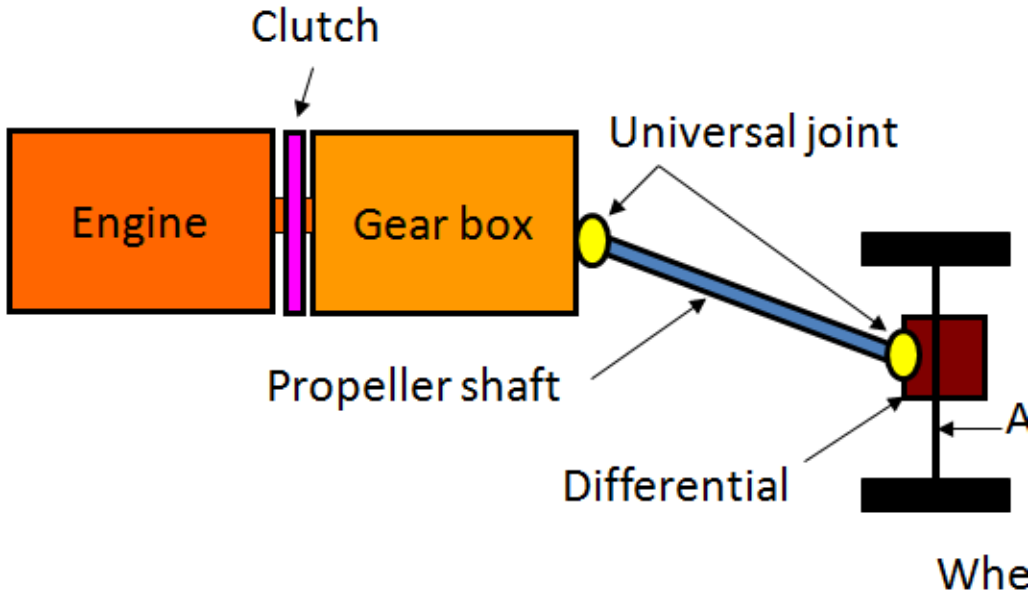
(a) Leather:Dryleatheroniron has coefficient in friction of 0.27.
(b) Cork:Corkondrysteeloriron has coefficient of friction of 0.32.
(c) Fabric:Goodqualityfabricmaterialshavecoefficientoffrictionofabout 0.4.Buttheycannotbeusedathightemperatures.
(d) Asbestos:Asbestosfacinghave coefficientof friction of about0.2. However it has got anti-heatcharacteristics.
(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 whatever 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

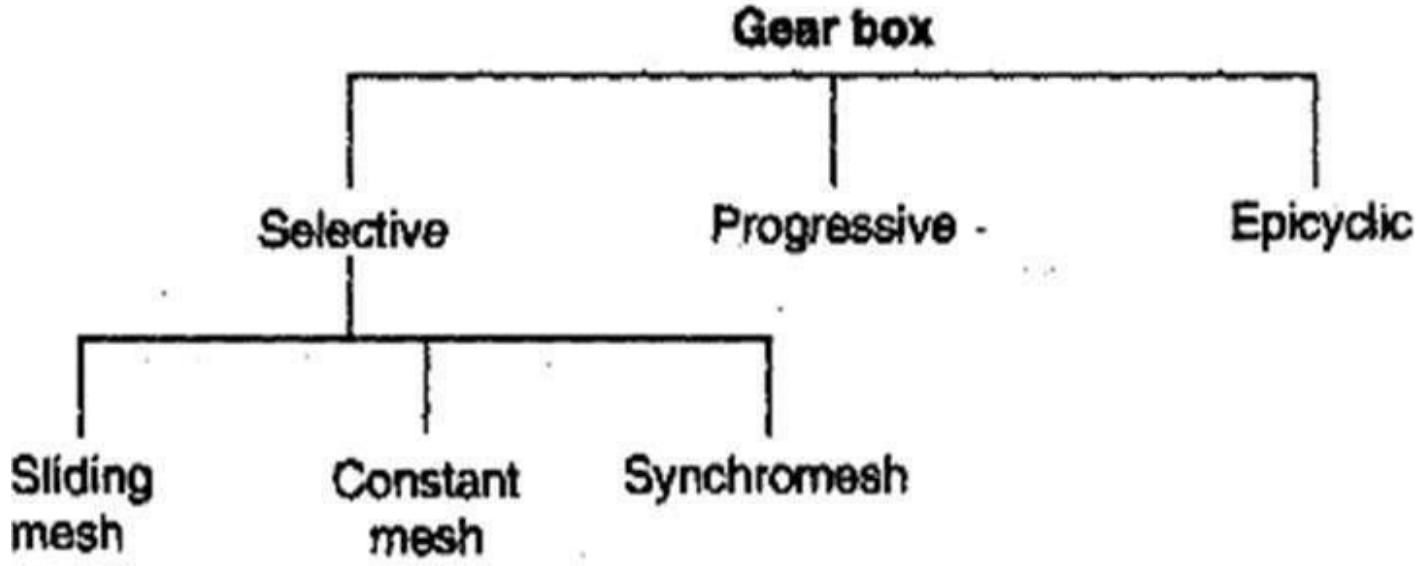
- Total resistance to the vehicle motion consists of:

(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



SelectiveType 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 (3to 5 steps), making it necessary to shift gears each time when vehicle running condition change.

Sliding Mess Gear Box

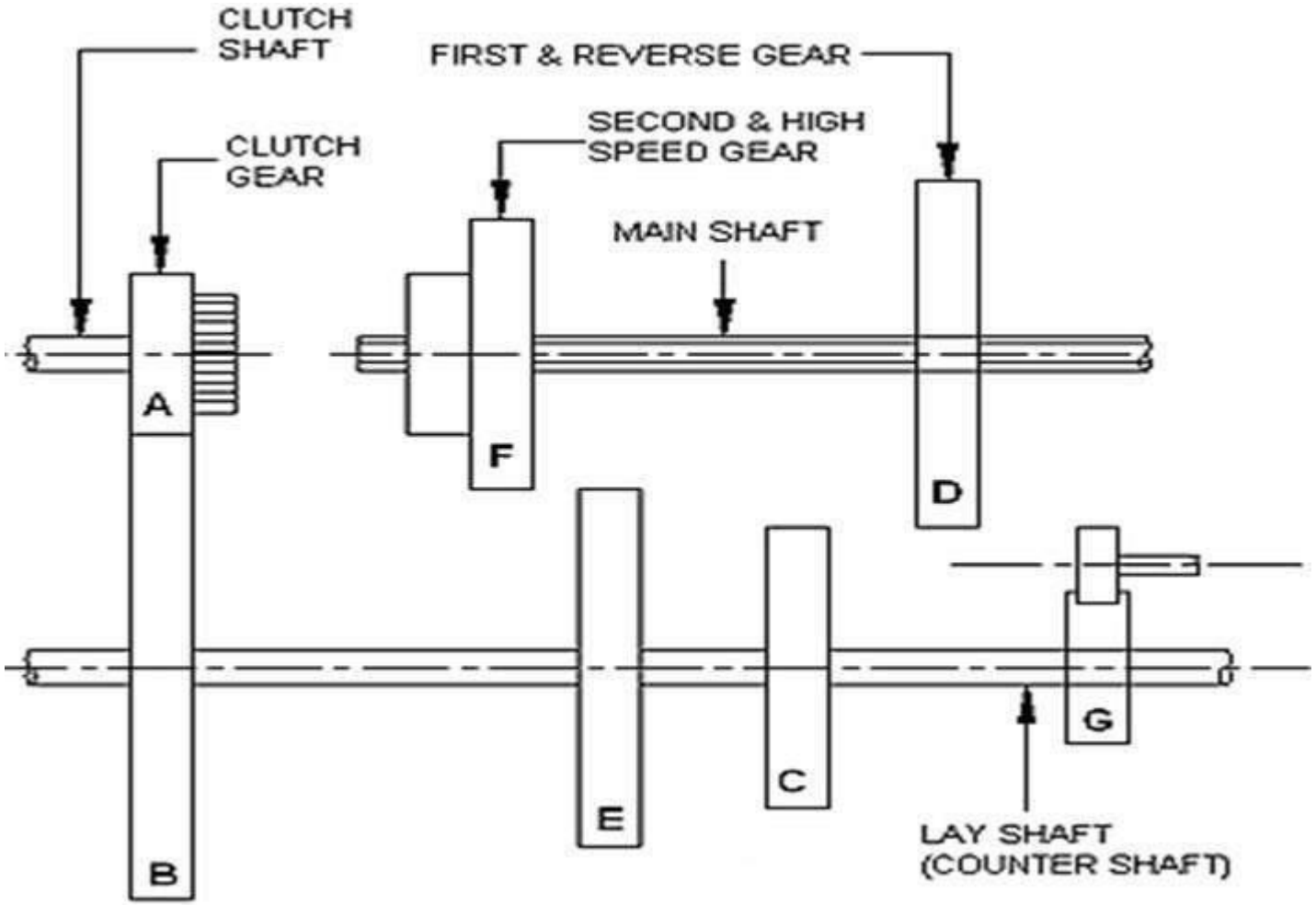
- Itisthesimplestandoldesttypeofgearbox.
- Theclutchgearisrigidlyfixedtotheclutchshaft.
- Theclutchgearalways remainsconnectedtothedrivegear of countershaft.
- Theotherlayshaftgearsarealsorigidlyfixedwithit.
- Two gears are mounted on the main shaft and can be sliding by shifter yoke when shifter is operated.
- Onegear is second speed gear andthe other is thefirst and reverse speedgears. All gears used are spur gears.
- Areverseidlergearismountedonanothershaftand always remains connected to reverse gear of counter shaft.
- Spurgearsareusedinslidingmessgearbox.

SlidingMessGearBox

- 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 is1:1.
- 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.

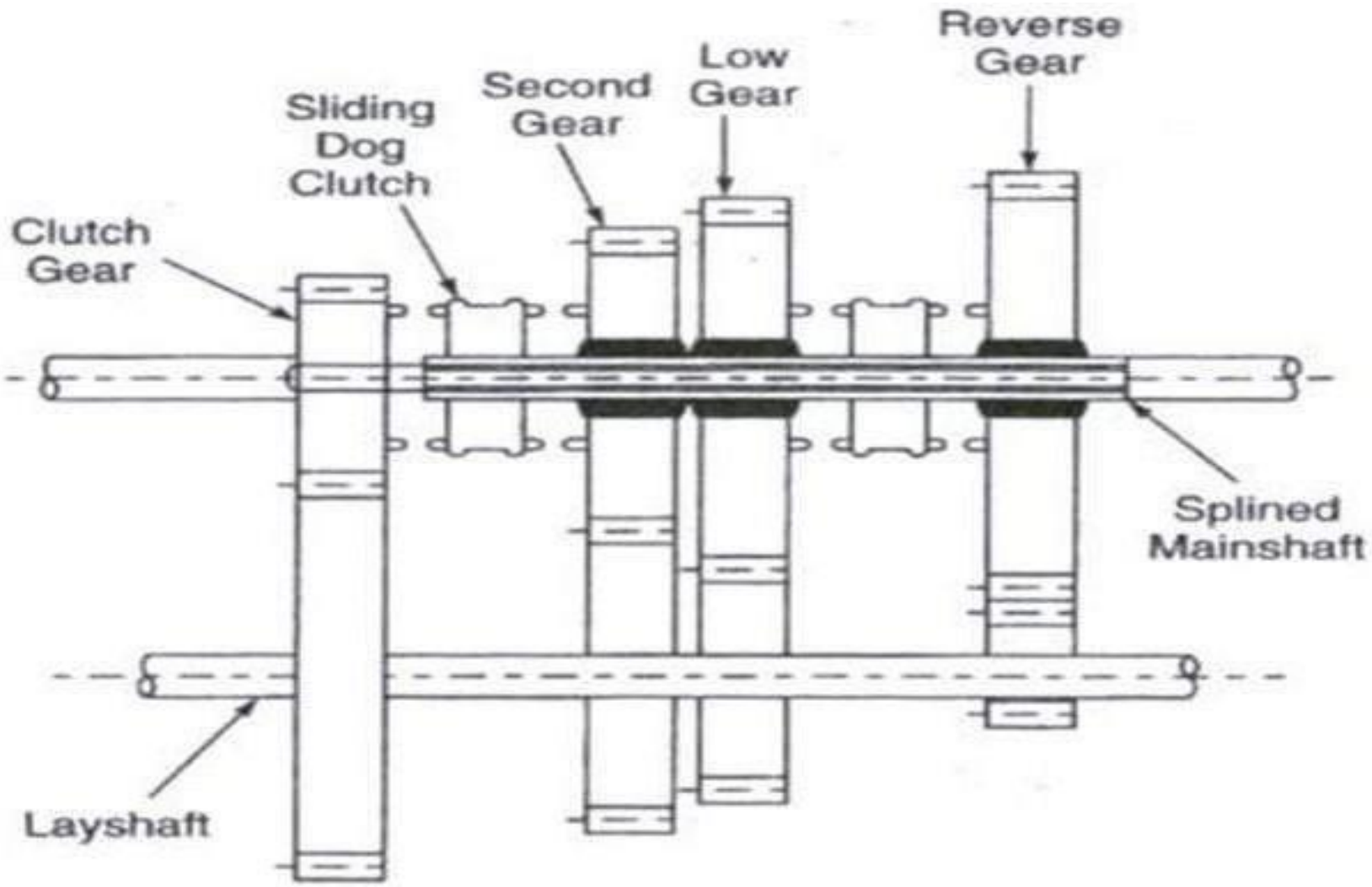
Sliding Mess Gear Box



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 gearbox.

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.

SynchromeshGearBox

- 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) Aringhavinginternalteeth

(ii) Synchromeshcones,maleC&femaleD

(iii) ToottheddogsA&B

- The ring is normally held in place by spring loaded balls. It rotates with theoutput shaft & also be slided along the splines cut onthe shaft.
- Figure 5.7 a shows disengaged position. Neither the male synchronizer cone C mesh with its female one D, nor the male toothed dogA overrides the female toothed dog B.
- theinputshaft,layshaft&gearsarerunningfree.

SynchromeshGearBox

- 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 betweenthem eitherspeedupor slowsdownthegearE w.r.ttheout 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 lockedtotheoutputshaft,wecallitasituationofgearengagement.

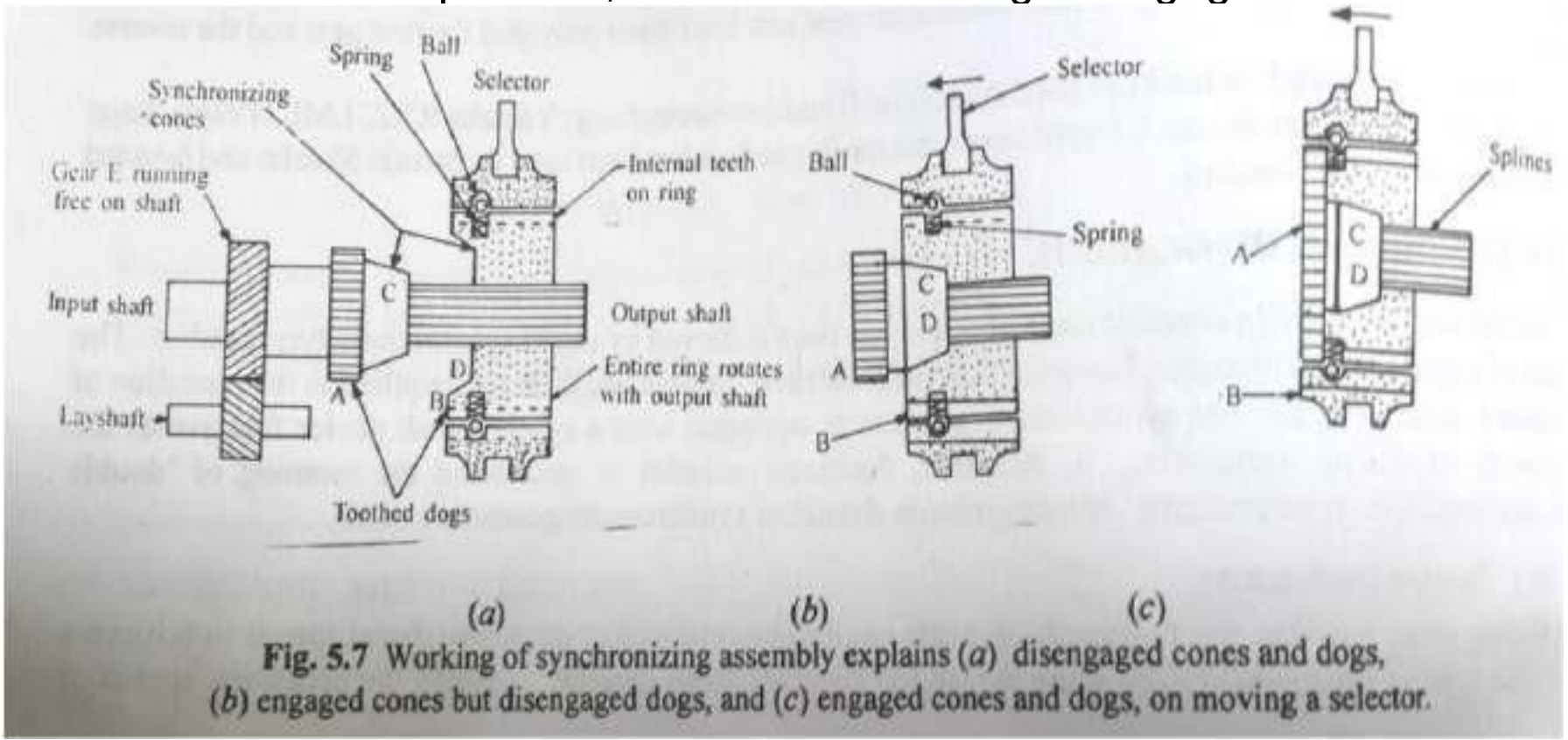


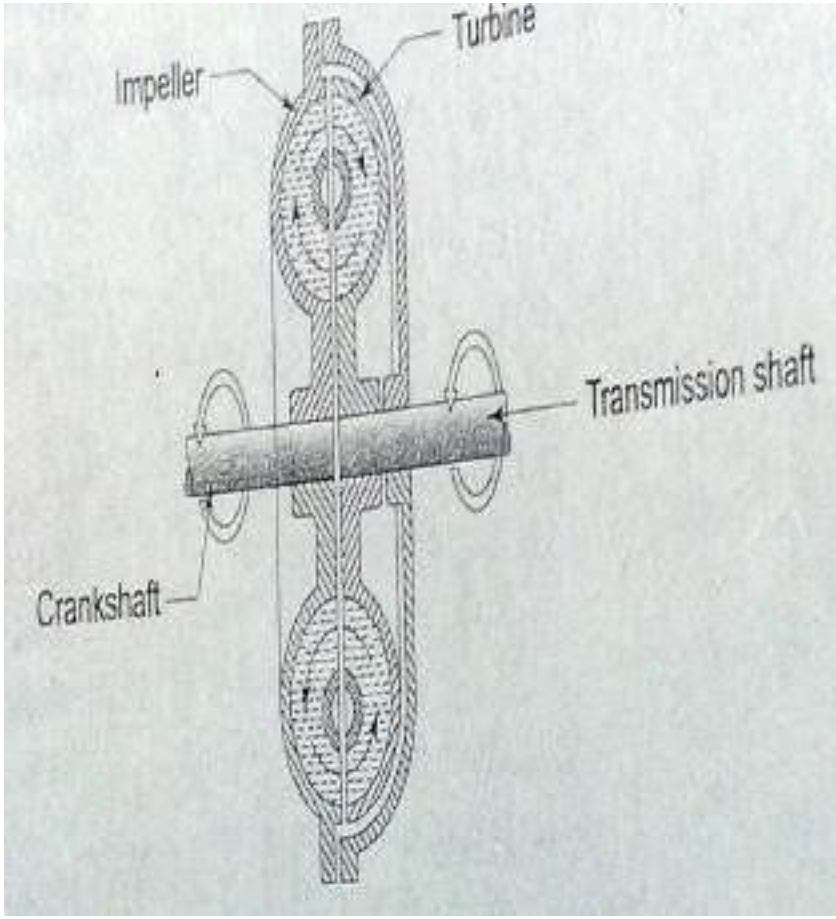
Fig. 5.7 Working of synchronizing assembly explains (*a*) disengaged cones and dogs, (*b*) engaged cones but disengaged dogs, and (*c*) engaged cones and dogs, on moving a selector.

Fluidflywheel

- 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.

Fluidflywheel

- 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 betweenthe 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 thetransmission shaft.



Fluidflywheel

- Advantages:

(i) Nowearonmovingparts.

(ii) Noadjustmentisnecessary.

(iii) Carcanstopingearandmove offalsobypressing accelerator pedal only.

(iv) Simpledesign.

(v) Nomaintenancenecessaryexceptoillevel.

(vi) Noskillrequiredforoperatingit.

- 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.

Torqueconverter

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

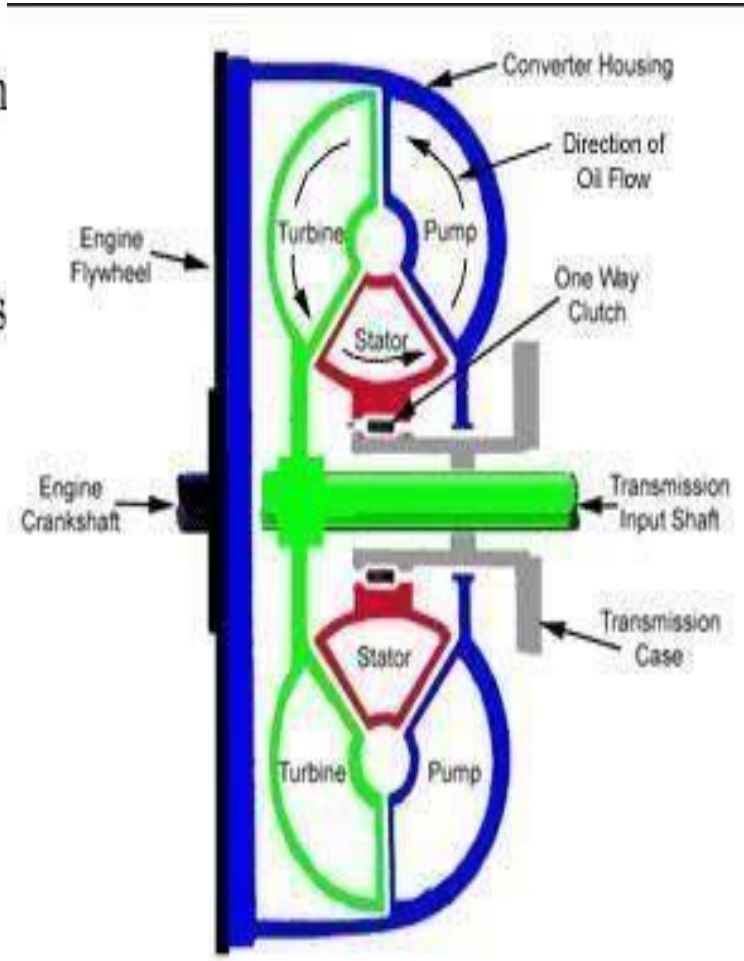
The stator is located between the impeller and the turbine. It is mounted on the stator reaction shaft which is fixed to the transmission case. The vanes of the stator catch the fluid as it leaves the turbine runner and redirects it so that it strikes the back of the vanes of the impeller, giving the 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.

Torqueconverterworkingoperation

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.

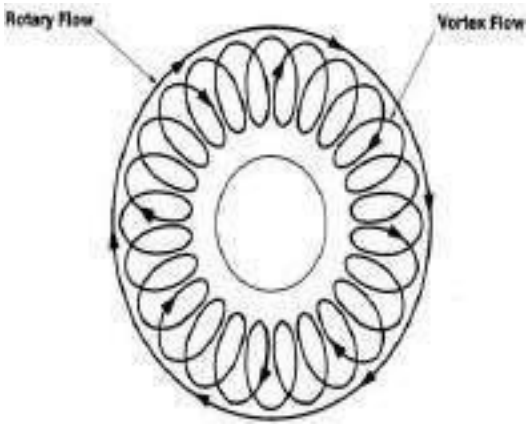


➢ Torqueconverterfluidflow:

- Followingtypesofflowdevelopedduringoperationofconverter:

a. Vortexflowoccurswhilevehicleisaccelerating(impellerturning faster than turbine).

b. Rotaryflowoccurswhilevehicleiscrusing(impellerandturbine at all most same speed).



➢ Phasesofoperation:

a. Torquemultiplication:
- Relativelylowimpeller(engine)RPM’s
- Statorislockedintoplacebyitsone-wayclutch
-Vortexfluidflowwithintheconverter

b. Couplingphase:
- Occursatnormaldrivingconditions
- Notorquemultiplication
- Statorisfreewheeling
- Turbineisspinningatapprox90%ofimpellerspeed
- Rotaryflowwithintheconverter

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

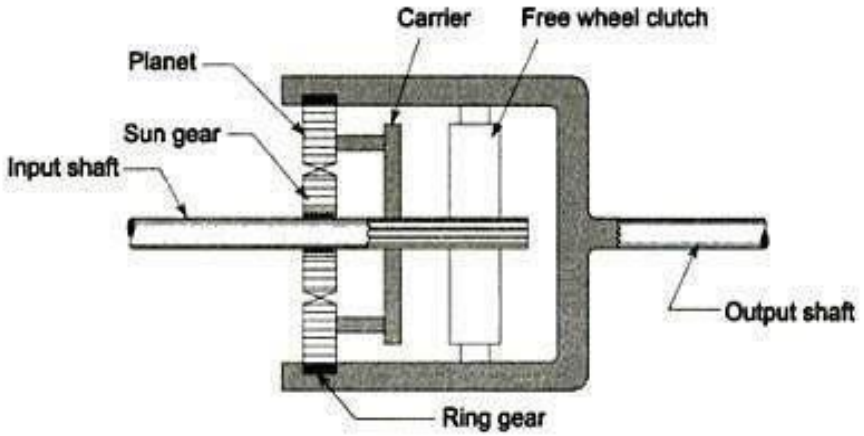
Advantages

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-automatictransmission**(SAT)(alsoknownasa **clutchlessmanual transmission**, **automated manual transmission, flappy-paddle gearbox**, or **paddle-shift gearbox**) is anautomobile transmission that does not change gears automatically, but ratherfacilitatesmanualgear changesbydispensing withthe 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.

- Asemi-automatictransmissionisaveryadvancedsystem,

whichstillusesaclutchtoperformthegearshiftinsteadof 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 fromstalling when the car is stationary.

- **Thetwomostcommonsemi-automatictransmissions are direct shift transmission (aka dual-clutch transmission) and electrohydraulic manual transmission (aka sequential transmission)**

Propellershaft

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

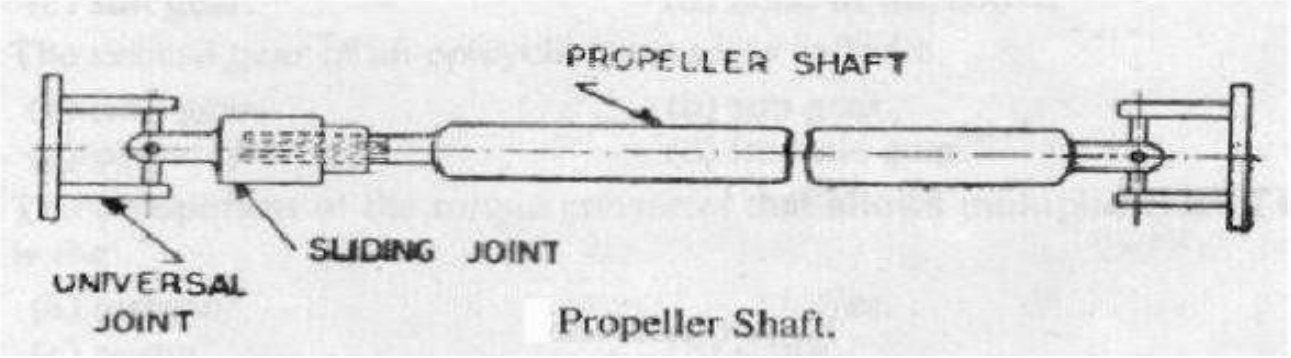
1. Transmitthepowerfromgearboxtopfinaldive.
2. Tocompensatethechangeinlength.
3. Transmitmotionatananglewhichisvaryingfrequently.

- 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.
- Propellershaftismanufacturedinthinwalledsteeltube.

Propellershaft

- Thepropellershafthasfollowingthreecomponents:

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.



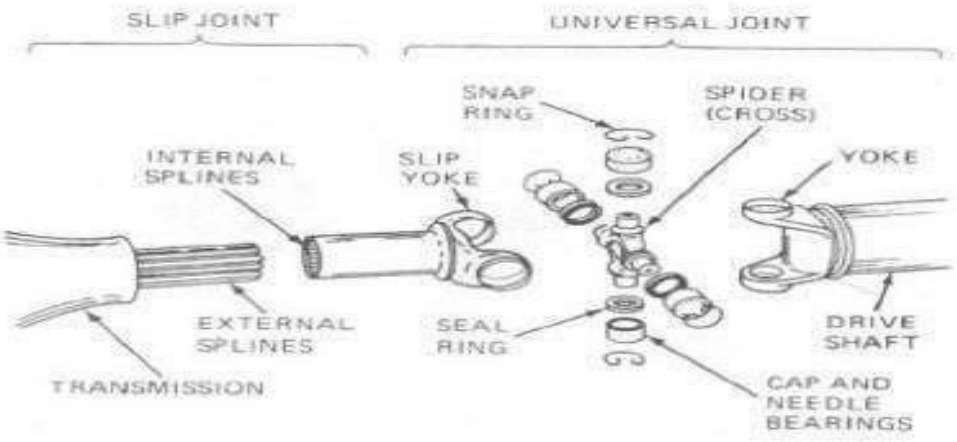
Propeller Shaft.

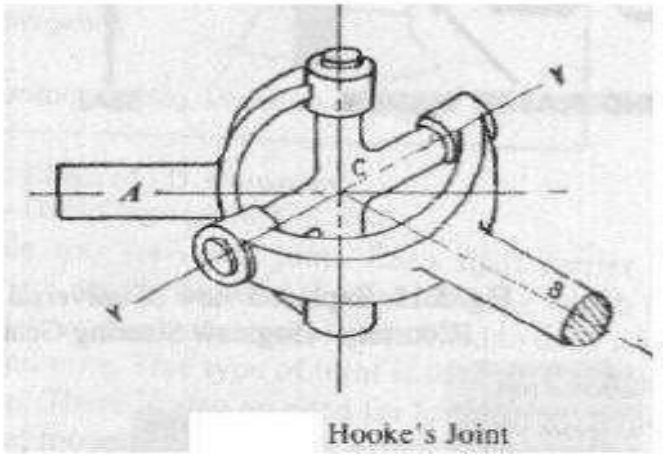
Universaljoint

- The purpose of universal joints is to transmit power (torque) even at varied angles of thetransmission 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 bymeans of theuniversal joint.The differential is connected to the other end of the propeller shaft by means of another universal joint.
- Themostcommontypeof universaljointisHook's Joint.

Crosstypeorspider&twoyoke(Hook'sJoint)

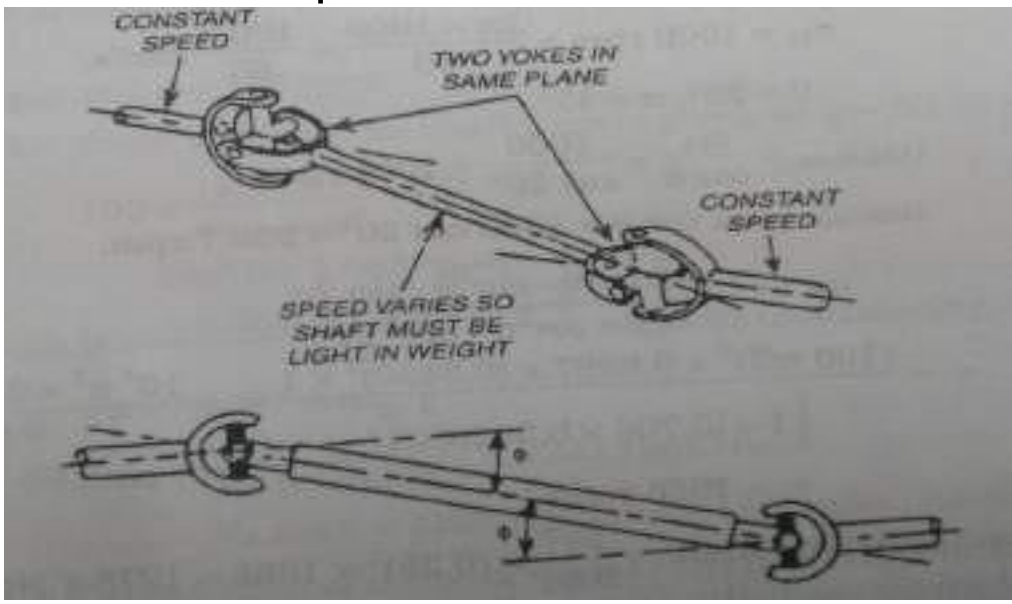
- A single universal joint is shown in fig, there is a driving yoke on one side which is connected to the main shaft of the gear box & the driven yoke is connected to the propeller shaft. These two yokes are connected by means of a crossed spider. When the driving shaft rotates, thedriven shaft also 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 thepropeller shaft at any particular angle.
- Universal jointshave one common defect i.e. the speed of the driven shaft does not remain constant. Depending upon the angle ofinclination of the shafts, driven shaft speed undergoes cyclic variation as shown in fig.





Constantvelocityuniversaljoint

- This type of joints permitmovement of both driving & drivenshaft at constant velocity.
- Onemethodtoachieveauniform drivenshaftspeedisbyusingtwo such joints as shown in fig.
- Theintermediateshaftissoarrangethatitmakesequalangleswith first and third shifts.
- Thevariation caused byonejoint is then cancelled out bythe second joint.
- however,this willbevalidonlywhentheanglesonbothjointsare exactly equal, which is not always the case in practice.



Constantvelocityjoint

1. Constant velocityjoints are used where thefront 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.

Finaldrive

- Inmostautomobilevehiclesthefinaldriverisembodiedinrearaxle.
- But in various popular vehicles with front wheel drive and a few special purpose vehicles with four wheel drive, itbecomes necessary to consider final drives as units dependent of their positions.

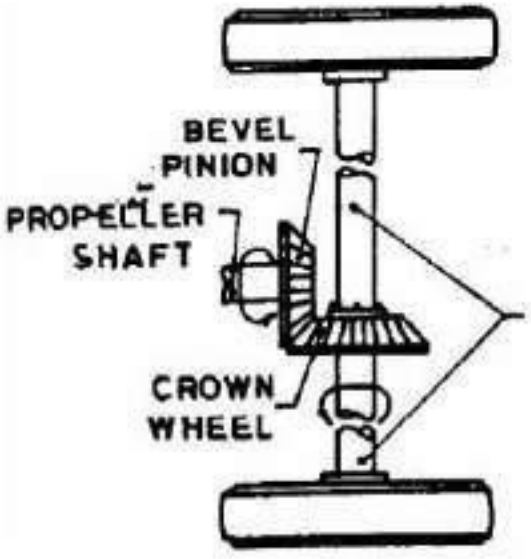
➢ FUNCTIONSOF FINAL DRIVE: Inamotorvehiclethefinaldrive has two purposes.

1) To provide a permanent speed reduction. For motor cars thereduction is usuallyabout 4:1 and 10:1 in heavy vehicle.
2) Toturnthedrivethrough90^{o}sothatthetorquemaybetransmitted from propeller shaft to the rear axle.

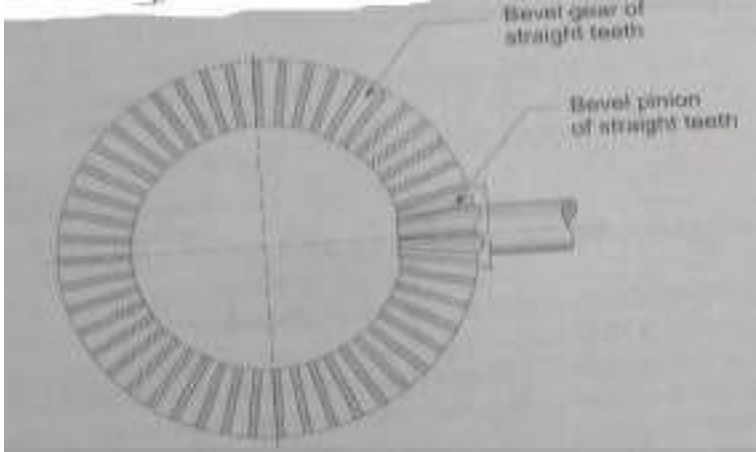
Constructionoffinaldrive

1) Thefinaldrive consistof abevel pinionandcrown wheel (ring gear)as shown in the figure.
2) Thebevelpinionismountedon theshaft
3) Fromthecrownwheelthedrivegoestotherearaxle through the diffrential.
4) Therearethreetypesofthefinaldrivegearing:

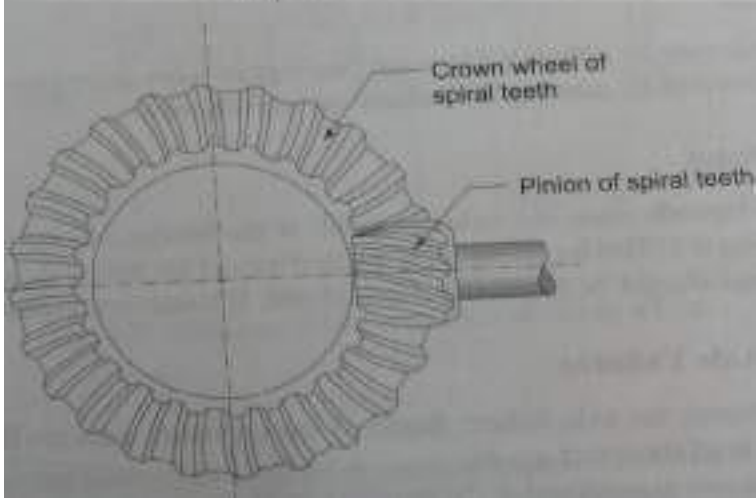
a. StraightBevelgears
b. SprialBevelGears
c. HypoidGears



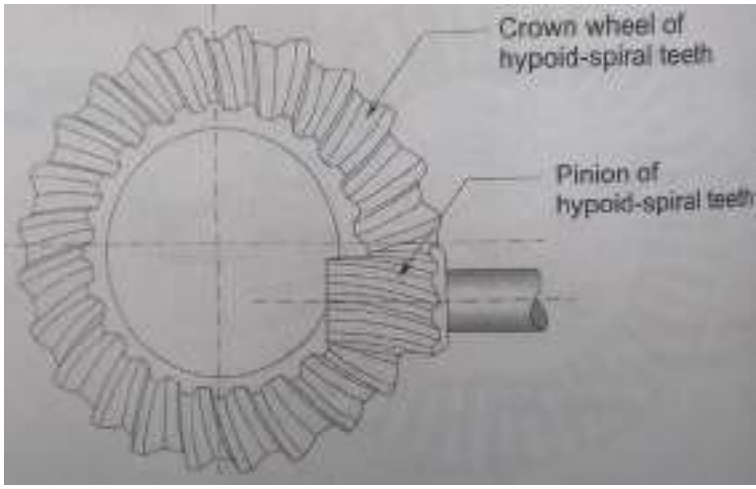
- Straight Bevelgears: this is thearrangement made in the older models.In this, the teeth of the crown wheel are straight. A bevel pinion of the propeller shaft is in mesh with the bevel gear of the crown wheel.



- 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 tootherunning is noiseless.



Constructionoffinaldrive

1) Finaldriveisthelaststageintransferring powerfromengine to wheels.
2) Itreducesthespeedofthepropellershaft(drive shaft)to that of wheels.
3) Italsoturnsthedrive oftheпropellershaft byanangle 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) Finaldriveisoftwotypes, i.e.chaintypeandgeartype.
7) Forfinalreductioninspeedtwotypesofgearscanbeused.
8) Oneofthemmaybeuseof bevelgearsandanothermaybe worm and worm wheel.
9) Worm and worm wheel combination provides large reductionwithoutemploying largergears.Itisstrongalso.

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 thetwo rear wheels are rigidlyfixed to asolidrear axle, the inner wheel will slip, which will cause rapidtirewear, 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.

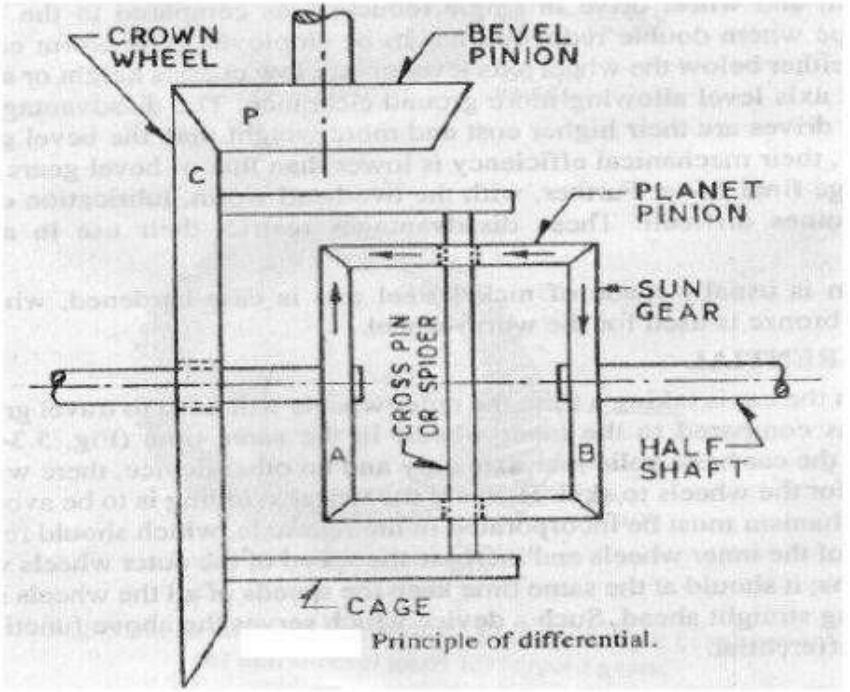
Differential

- 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. Twosun gears meshwiththetwoplanetpinions. 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. Tounderstandwhathappenswhenthevehicleistakingturn,assume thatthecage is stationary. Thenturninganyonesun gear willcause 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. Thusforexample,consideravehiclewithwheelspeed"N" r.p.m. going straight. When it takes turn towards, there will be resistance to the motion of right wheel & asaresult 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.

Nonslipdifferential

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

- Non-sliporlimitedslipdifferentialorself lockingtype differential overcomes this drawback:

1) Aself locking differentialconsistsof twoclutches,oneoneach 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 mountedontwocrossshaftsatright anglestoeach other.
3) When the differential cage is driven bythe 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 bearagainst the side gear rings in order to apply the clutchwhich locks both axle shafts andforce them to turn at the same speed.

DifferentialLock

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 dirtor sand the wheelonthe 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.

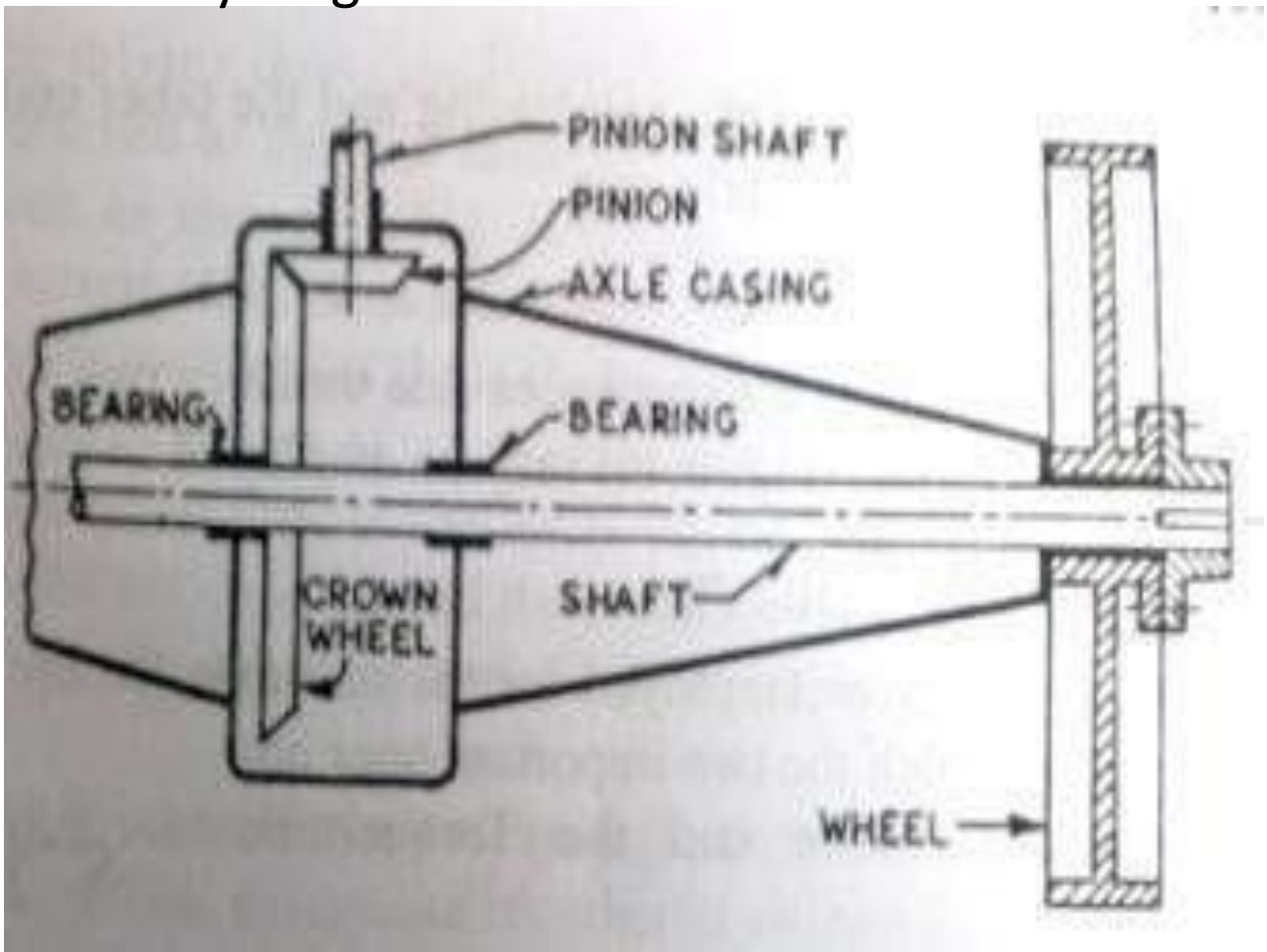
Rearaxle

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.

RearAxel

Functionofrearaxel:

1. Totransmitpowerfromdifferentialtowheels
2. Tocarryweightofautomobile.



Rearwheeldrive

- Commonlyusedrearwheeldriveare:

1. Hotchkissdrive:
2. Torquetubedrive:

Rearaxeldrive

1. Hostchkissdrive:

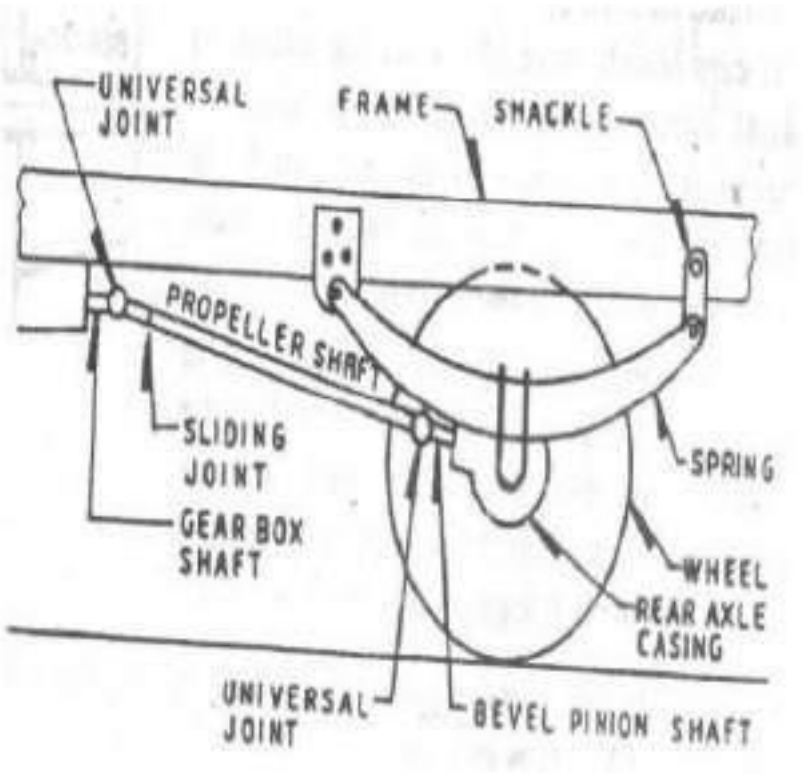
a) This is the simplest and most widely used type of rear axle drive.

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 theframe while the rear end is supported in the shackle.



Rearaxeldrive

2. Torquetubedrive:

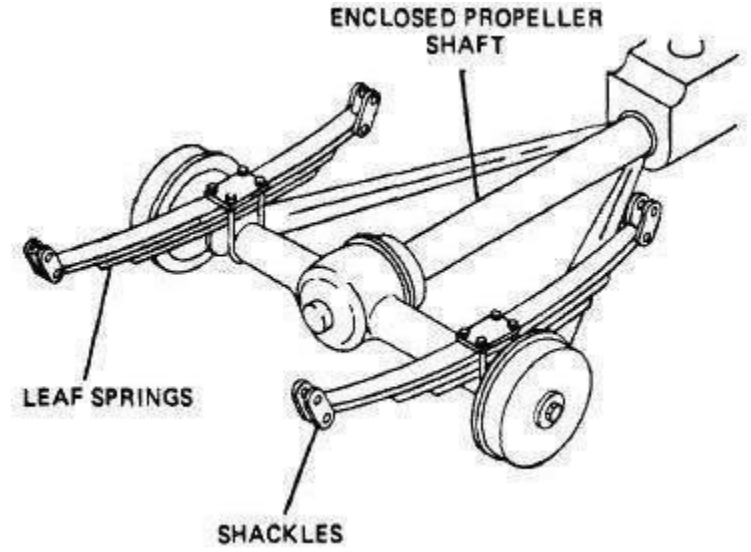
a. In this type ot drive the spring takes only the side thrust besidessupporting the body weight.

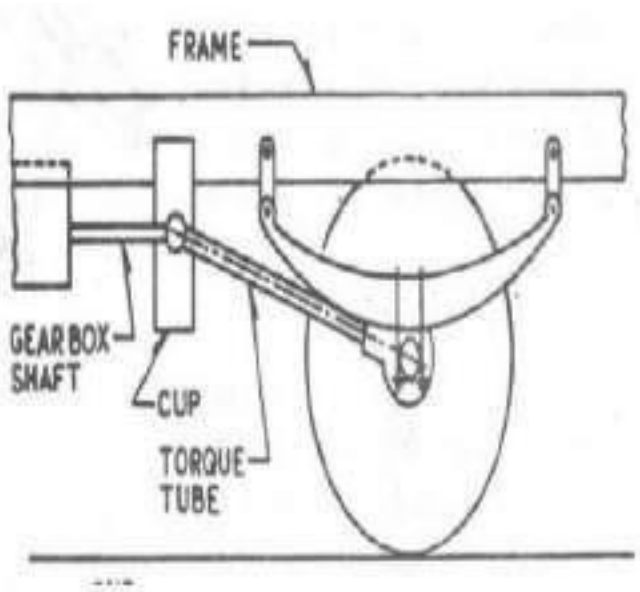
b. The torque reaction and driving thrust aretakenbyanothermemberwhichis called torque tube.

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.





Rearaxelshaftsupporting

- **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:

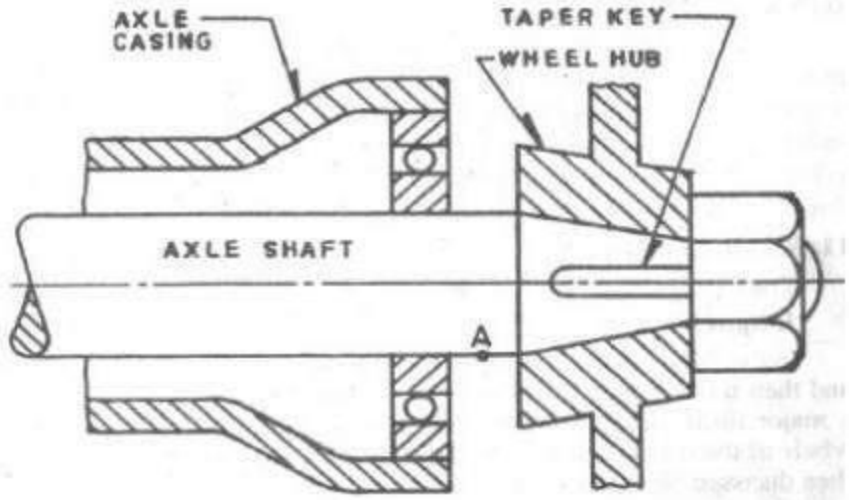
(a) Half floating axle /semifloatingtype

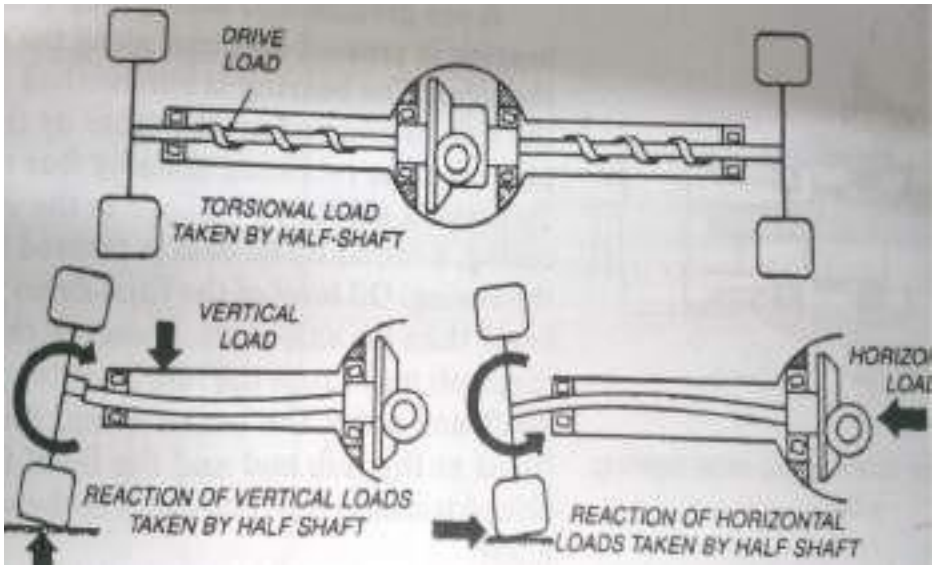
(b) Three-quarter floating axle

(c) Fully floating rear axle.

1. Semifloatingtyperearaxel:

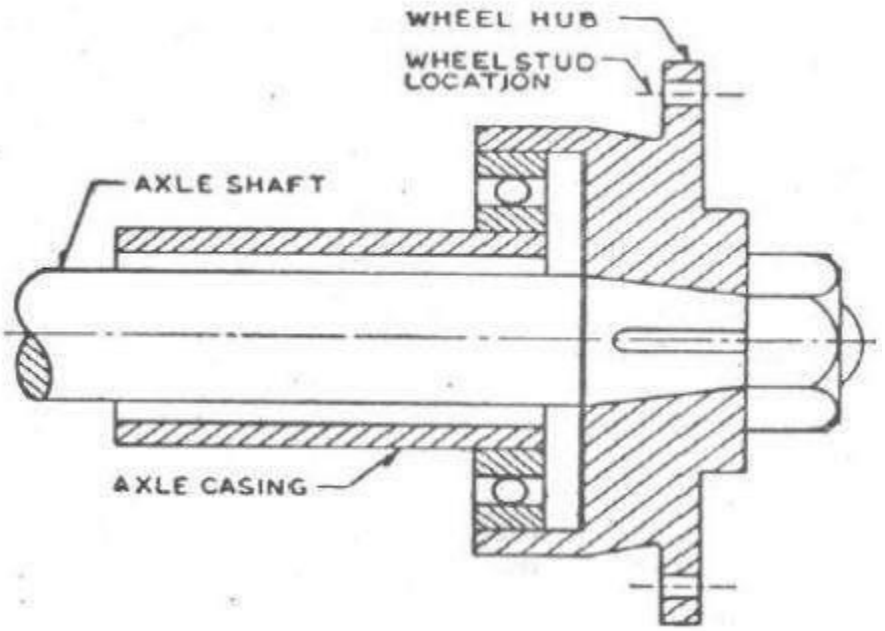
1) An axlein which the shaft has to take the entire load is called semi or non floating axle.
2) In this wheel hub is directly connected to the axle.
3) The inner end of the axle shaft is splined and is supported by the final drive unit where as outer end is supported by a single bearing inside the axle 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 sametorquetransmittedcomparedto the other type of rear axle supports.

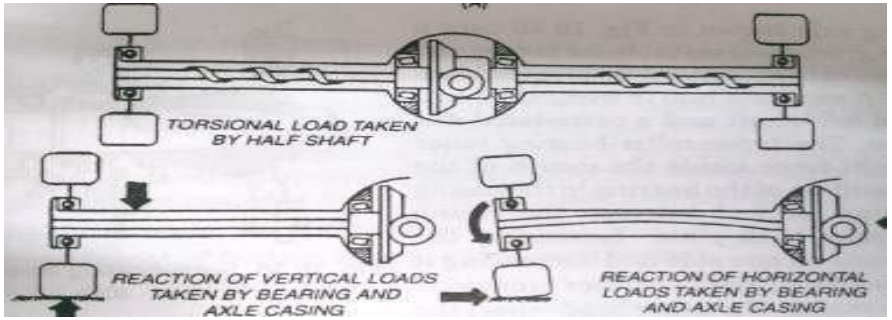




2. Threequarterfloatingaxle:

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.





IGNITIONSYSTEMS&FUEL INJECTION SYSTEMS

IgnitionSystem:

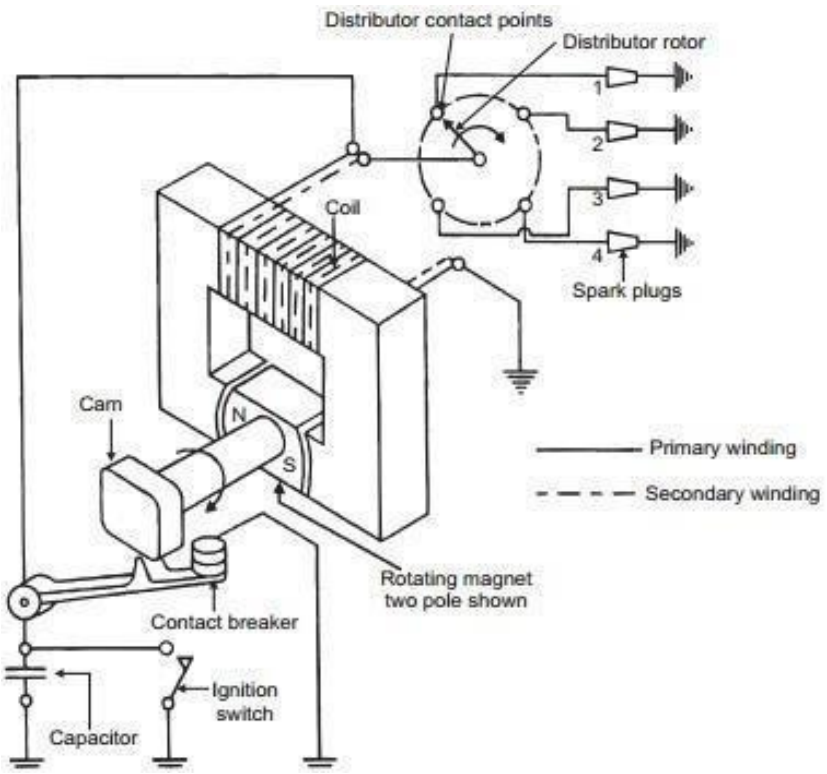
The ignition system is a system used to generate a very high voltage from the car batteryandtosendittoeachsparkpluginturn therebyignitingthefuel-airmixtureinthe combustion chamber of the engine.

TypesofIgnitionSystem:

1. Magnetoignitionsystems
2. Batterycoilignitionsystems
3. Electronicignitionsystem

Magnetoignitionsystems:

This type of ignition system is mostly used in motorcycles,scootersandracingcars.Themagneto Ignition system with main components is shown below:



Schematicofrotatingmagnettypemagnetoignition systems

Magneto ignition system is a special type of ignition system with its own electric generator to provide the required necessary energy for the vehiclesystem.Itismountedontheengineand replacesallcomponentsof thecoilignitionsystem exceptthesparkplug.Amagnetowhenrotatedby the engine is capable of producing a very high voltage and doesn’t need a battery as source of external energy.

Themaincomponentsofanignitioncoilare

Distributor,Condenser,ContactBreaker(CB) points, Ignition Coil.

Therearetwoimportanttypesofmagneto ignitionsystem.Theyare1)Rotatingarmature type and 2) Rotating Magnet type.

In the first type, the armature consisting of the primary and secondary windings rotate in between thepolesof astationarymagnet.Inthesecondtype themagnetrevolvesandwindingsarekept 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 byreversing the flux field with the help of soft iron polar projections called inductors.

Condensor:

Thefunctionofthecapacitoristoreducearcing atthecontactbreaker(CB)points.Alsowhenthe CB opens the magnetic field in the primarywinding

begins to collapse. When the magnetic field is collapsing capacitor gets fully charged and then it starts dischargingandhelpsinbuildingupofvoltage in secondary winding.

ContactBreaker:

ItistobenotedthattheContactbreakercam anddistributorrotoraremountedonthesame shaft.

Distributor:

IgnitionCoil:

The main advantage of the high tension magnetoignitionsystem istheproductionofavery high voltage.Because of the poor starting characteristics of the magneto system invariably

the battery ignition system is preferred to the magnetosysteminautomobileengines.However,in two wheelers magneto ignition system is preferred due to light weight and less maintenance.

Batterycoilignitionsystems:

It is used in passenger cars and light trucks. A Battery Ignition system for four cylinder engine wherethebatterysuppliestheelectricalenergy.An ignitionswitchisusedtocontrolthebatterycurrent 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 jumpinginaspark plug.Thedistributordeliversthe 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.Thesparkplugsprovide thesparkin engine cylinder.

Thefigureshowsbatteryignitionsystem fora4-cylinderpetrol engine. It mainlyconsistsof a 6 or 12 volt battery, ammeter, ignition switch, auto-transformer (step up transformer), contact breaker, capacitor, distributorrotor, distributorcontactpoints,

sparkplugs,etc.

Theignitionsystemisdividedinto2-circuits namely the PrimaryCircuit and Secondary Circuit.

(i) Primary Circuit : It consists of 6or12Vbattery,ammeter, ignition switch,primary winding it has200-300turnsof 20SWG(SharpsWireGauge)gaugewire,contactbreaker,capacitor.53

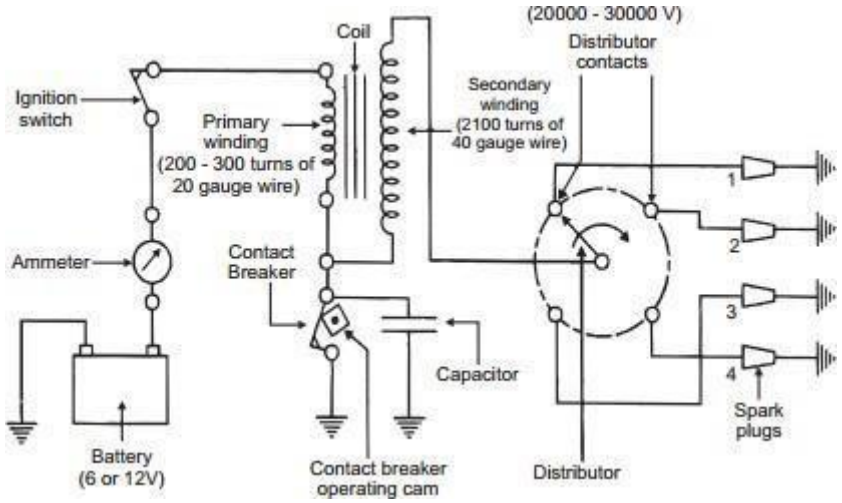
(ii) Secondary Circuit: It consists of secondary winding. Secondary Ignition Systems winding consists of about 21000 turns of 40 (SWG) gauge wire. Bottom end of which is connected to bottom end of primary and top end of secondary winding is connected to centre of distributor rotor.Distributorrotorsrotateandmakecontactswithcontactpointsandareconnectedtospark plugs which are fitted in cylinder heads.

Working:

When the ignition switch is closed and engine incranked,assoonasthecontactbreakercloses, a low voltage current will flow through the primary winding. When the contact breaker opens the contact, the magnetic field begins to collapse. Becauseofthiscollapsing magneticfield,current will be induced in the secondary winding. And becauseofmoreturnsofsecondary,thevoltage 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 thehighvoltagecurrentjumpsthespark pluggap,it producesthesparkandthechargeisignited-combustion starts-products of combustion expand and produce power.

When compared to the magneto ignition system, the battery ignition system is more expensive butatthesametimeitisveryhighly reliable as it aids in reliable sparking..



SchematicDiagramofbatteryignitionsystems

Electronicignitionsystem:

The requirement for higher mileage, reduced emissionsandgreater reliabilityhaspavedtheway for development of the electronic ignition systems.

Themainadvantagesoftheelectronicignition system are

Itprovidesbetteremissioncontrol.

It providesareasonablefueleconomy.Itprovides better

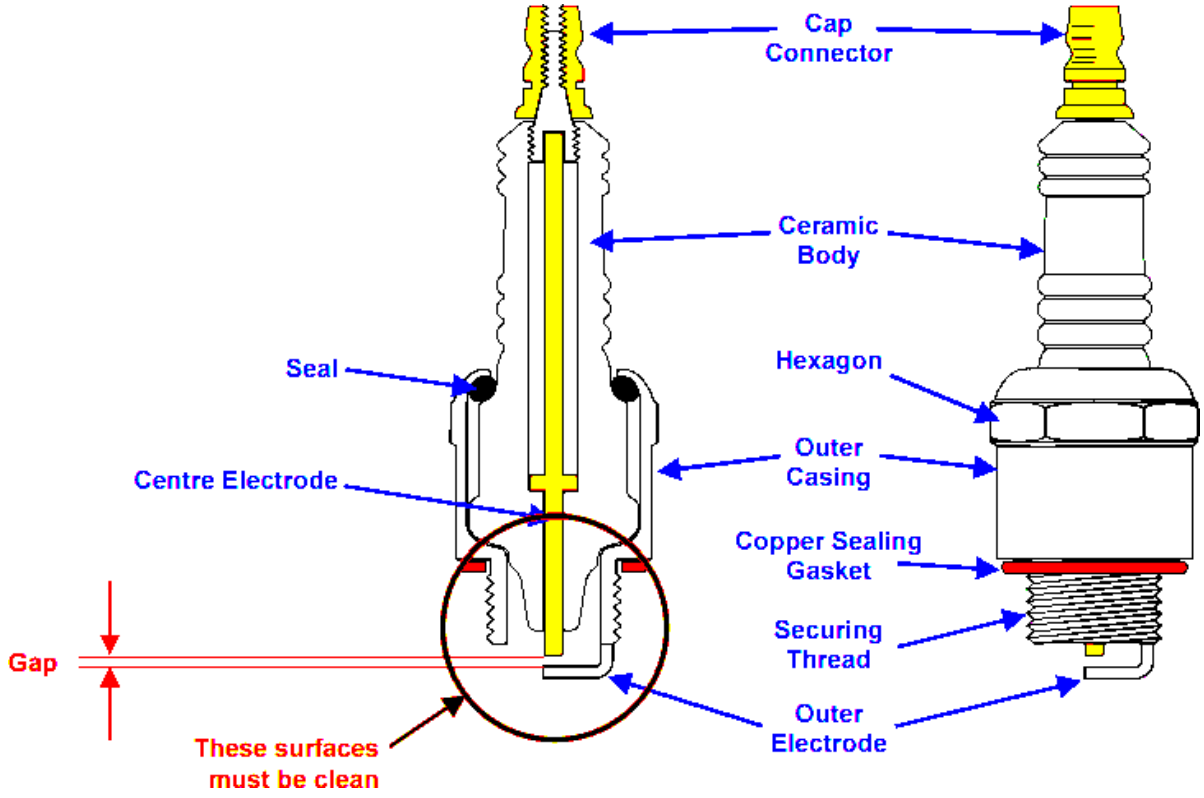
engine performance.

Sparkplug:

Thesparkplugconsistsofaporcelaininsulator inwhichthereisaninsulatedelectrodesupported 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 fromthe coilmustjumpafterpassingthroughthedistributor. The spark plugs use ignition coil high voltage toignitethefuelmixture.Somewhere between 4,000 and 10,000 volts are required to make

currentjumpthegapattheplugelectrodes. Thisismuchlowerthantheoutputpotentialof the coil.

Spark plug gap is the distance between the center and side electrodes. Normal gap specificationsrangebetween.030to.060inch. Smallersparkplugsgapsareusedonolder 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) designedtoreducethestaticinradios.Most new vehicles require resistortype plugs. Non-resistor spark plug has a solid metal rod forming the center electrode. This type of sparkplugsisNOT commonlyusedexceptfor racing and off-road vehicles.



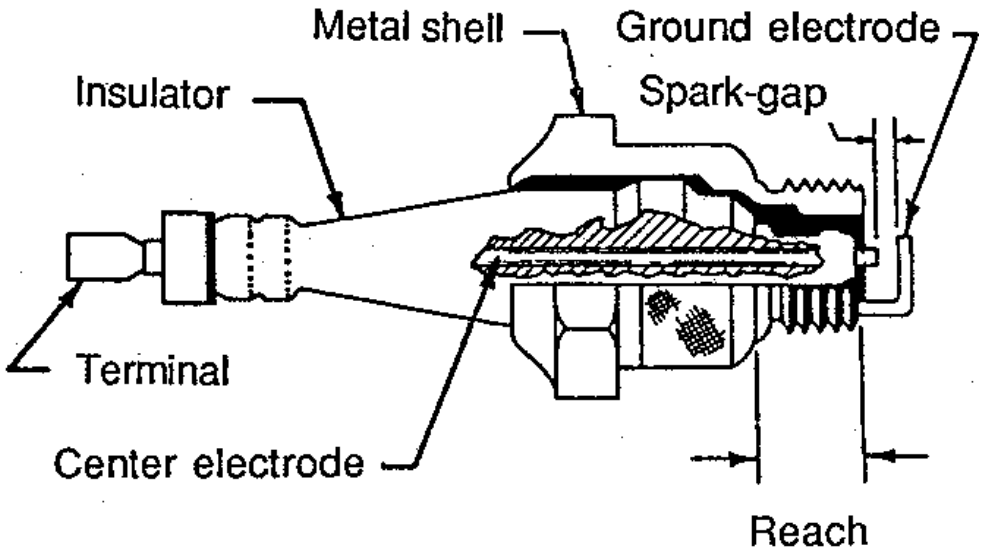
SparkPlugHeatRangeandReach:

Theheatrangeofthesparkplugdetermines how hot the plug will get. The length and diameteroftheinsulatortipandtheabilityof the spark plug to transfer heat into the cooling system determine spark plug heat range. Ahotspark plughasalonginsulatortipthat preventsheattransferintothewaterjackets. It will also bum off any oil deposits. This provides a self-cleaning action. Acoldsparkplughasashorterinsulatortip

andoperatesatacoolertemperature.The cooler tip helps prevent overheating and preignition. A cold spark plug is used in engines operated at high speeds. Vehiclemanufacturers recommendaspecific spark plug heat range for their engines. The heat range is coded and given as a number onthesparkpluginsulator.Thelargerthe numberonthe plug,thehotterthespark plug tipwilloperate.Forexample,a54plugwould 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.Forinstance, iftheplugrunstoo cool,sootycarbonwilldepositontheinsulator 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 sparkacrossthesparkpluggap.Usinga hotter plug will bum this carbon deposit away

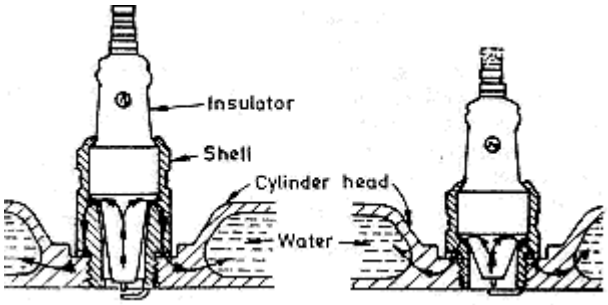
orpreventitfrom forming.
Sparkplugreachisthedistancebetweenthe endof the spark plug threads andthe seator sealing surface of the plug. Plug reach determineshowfartheplugreachesthrough the cylinder head. If spark plug reach is too long, the spark plug will protrude too far into the combustion chamber and the piston atTDCmaystriketheelectrode. 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.Asparkplugmustreachintothe combustion chamber far enough so that the spark gap will be properly positioned in the combustionchamberwithoutinterferingwith the turbulence of the air-fuel mixture or reducing combustion action.



Sectionalviewofa(A)non-resistorand(B)resistorsparkplug.

ConstructionofSparkPlug:

Typesofsparkplugs:



Introductiontocarburetorsystems:

Carburetor is a device used for providing properair/fuelmixtureratio. Thecarburetorworks 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

fuelbyactuatingthecarburetormechanismswhich metersthe flow of air being pulled into theengine. Thespeedofthisflow,andthereforeitspressure, determines the amount of fuel drawn into the airstream.

The latest type of carburetor system is the electronicfeedback design, which providesbetter combustion by improved control of the air/fuel mixture. A three-way converter not only oxidizes HCandCObutalsochemicallyreducesoxidesof nitrogen(NOX).Iftheair/fuelmixtureistoolean, NOX is not converted efficiently. If the mixture is too rich, HC and CO does not oxidize efficiently. Monitoringtheair/fuelratio isthejobofthe 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 exhaustbeforethecatalyticconverter,producesa 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 thesensorandinturn generateoutputsignalstoa 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 controltheair/fuelratio,thecarburetorissaidtobe 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,therearecertainconditionsunderwhich 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 functioninginconventionalmannerandissaidto beoperatinginopenloop.(Thecontrolcyclehas been broken.)

Thecarburetoroperatesinopenloopuntilthe oxygen sensor reaches a certain temperature (approximately 600F). The carburetor also goes intoopenloopwhenaricher-than-normalair/fuel mixture is required, such as during warm-up and heavy throttle application.
Several other sensors are needed to alert the electronicsensorprovidesinputrelatingtoengine 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 solenoidregulator,whichinturncontrolsvacuum to a piston and diaphragm assembly in the carburetor. The vacuum diaphragm andaspring

above the diaphragm work together to lift and lower a tapered fuel metering rod that moves in andoutofanauxiliaryfueljetinthebottom ofthe fuel bowl. The position of the metering rod in the jetcontrolstheamountoffuelallowedtoflowinto 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 openingcommunicatingcontrolvacuum tothefuel bowl. The larger this area, the leaner the air/fuel mixture.Someofthecontrolvacuumisbledoff 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.

COOLINGSYSTEM

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

NECESSITYOFCOOLINGSYSTEM

ThecoolingsystemisprovidedintheICengineforthefollowingreasons:

- The temperature of the burning gases in the engine cylinder reachesupto1500to 2000°C,which is abovethe meltingpointof thematerialofthe cylinderbodyandheadoftheengine.(Platinum, ametalwhichhasoneofthehighestmeltingpoints,meltsat1750 °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 veryhigh 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 stressessetup.This makes it necessaryfor,the temperature variationtobe kept to a minimum.
- Higher temperatures also lower the volumetric efficiency of the engine.
-

REQUIREMENTSOFEFFICIENTCOOLINGSYSTEM

Thetwomainrequirementsofanefficientcoolingsystemare:

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 ishot.During the starting of the engine, the cooling should be very slow so that the differentworkingpartsreachtheiroperatingtemperaturesin a shorttime.

TYPESOFCOOLINGSYSTEM

Therearetwotypesofcoolingsystems:

(i) Aircoolingsystemand
(ii) Water-coolingsystem.

AIRCOOLINGSYSTEM

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) Thetotalareaofthefinsurfaces,
(ii) Thevelocityandamountofthecoolingairand
(iii) Thetemperatureofthefinsandofthecoolingair.

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.

AdvantagesofAirCooledEngines

Aircooledengineshavethefollowingadvantages:

1. Itsdesignofair-cooledengineissimple.
2. It is lighterin weight than water-cooledenginesduetothe absenceofwaterjackets,radiator,circulatingpumpandtheweight of the cooling water.
3. Itischeapertomanufacture.
4. Itneedslesscareandmaintenance.
5. This system of cooling is particularly advantageous where thereareextremeclimaticconditions inthearctic orwhere there is scarcity of water as in deserts.
6. Noriskofdamagefromfrost,suchascrackingofcylinderjacketsor radiator water tubes.

WATERCOOLINGSYSTEM

Itservestwopurposesintheworkingofanengine:

a) It takes away the excessive heat generated in the engine and saves it from over heating.
b) Itkeepstheengineat workingtemperatureforefficient andeconomicalworking.Thiscoolingsystemhasfourtypes of systems:

(i) Directornon-returnsystem,
(ii) Thermo-Syphonesystem,
(iii) Hoppersystemand
(iv) Pump/forcedcirculationsystem.

Thoughthepresenttractorhasaforcedcirculationsystem,itisstill

worthwhiletogetacquaintedwiththeotherthreesystems.

Non-ReturnWaterCoolingSystem

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 lowH.P. engine, coupled with the irrigation pump is an example.

Thermo-SyphoneWaterCoolingSystem

This system works on the principle that hot water being lighter rises up and the cold water being heavier goes down. In thissystem the radiatoris placedat ahigherlevel thanthe engine fortheeasyflowof watertowards 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 waterfrom the radiatortakestheplaceoftherisinghotwaterandinthis wayacirculation of water is set up m the system. This helps in keeping the engine at working temperature.

DisadvantagesofThermo-SyphoneSystem

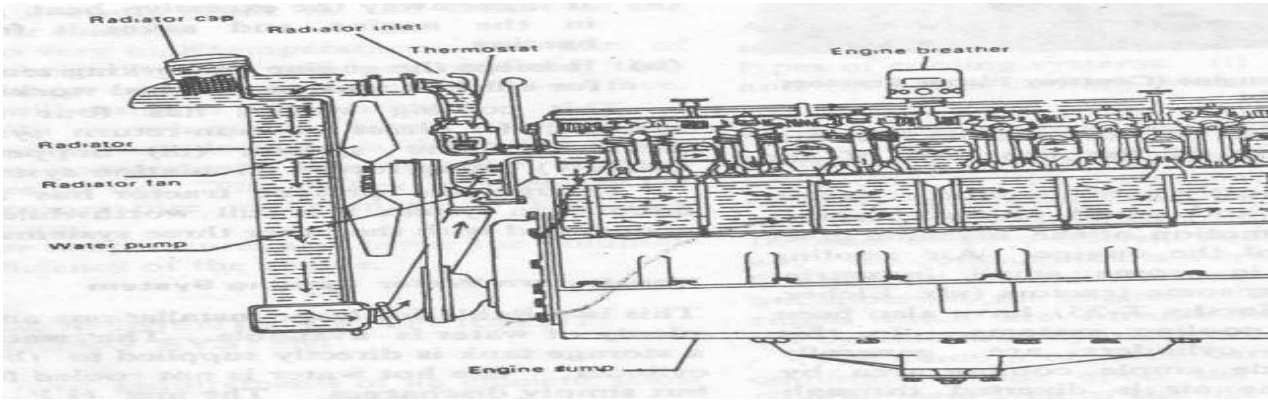
1 Rateofcirculationistooslow.
2. Circulationcommencesonlywhenthereisamarkeddifferencein temperature.
3. Circulation stops as the level of water falls below the top of the deliverypipe ofthe radiator. Forthesereasonsthissystemhasbecome obsolete and is no more in use.

HopperWaterCoolingSystem

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.

ForceCirculationWaterCoolingSystem

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 jacketsandradiator



The water flows from the lower portion of the radiator to the water jacketof 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.

PartsofLiquidCoolingSystem

Themainpartsinthewater-coolingsystemare:(i)waterpump,(ii)fan, (iii) radiatorandpressurecap,(iv) fan belt (v) waterjacket,(vi)thermostat valve, (vii) temperature gauge and (viii) hose pipes.

WaterPump

This is a centrifugal type pump. It is centrally mounted at the front of the cylinder block and is usuallydriven 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 mountedat the end of the crankshaft.

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

Fan

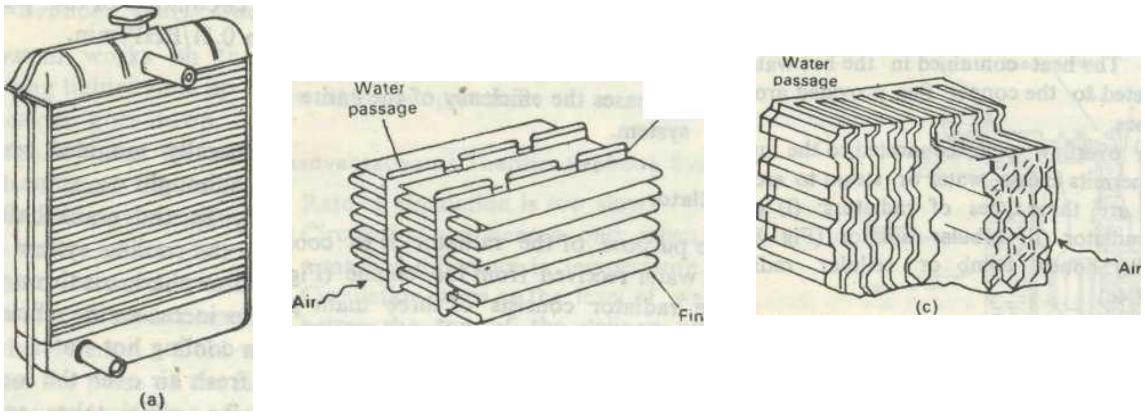
Thefanisgenerallymountedonthewaterpumppulley,althoughonsome engines it is attached directlytothe crankshaft. It serves two purposes in the cooling system of a engine.

(a) It draws atmospheric airthroughthe radiatorandthus increases theefficiencyoftheradiatorincoolinghotwater.
(b) It throwsfreshairovertheouter surfaceoftheengine, which takesawaytheheatconductedbytheenginepartsandthus increases the efficiency of the entire cooling system.

Radiator

The purpose of the radiator is to cool down the water received from the engine.Theradiatorconsists ofthreemainparts:(i)uppertank,(ii)lower tank and (iii) tubes.

Hot water from the upper tank, which comes from the engine, flows downwardsthroughthetubes.Theheatcontainedinthehot wateris 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 threetypes ofradiators:(i)gilledtuberadiator, (ii) tubularradiator(Fig.b)
and(iii)honeycomborcellularradiator(Fig.c)



Typeofradiators

Gilledtuberadiator:
Thisis perhaps theoldesttypeofradiator,althoughitisstill inuse.Inthis, water flows inside the tubes. Each tube has a large number of annular rings or fins pressed firmly over its outside surface.
Tubular radiator: Theonlydifference betweenagilledtubesradiatorand 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 largenumberofindividual aircells whicharesurrounded bywater. 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.

ThermostatValve
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 operatingtemperatureis reached, the thermostat valve opensand allows hot water to flow towards the radiator

Standard thermostats are designed tostart opening at 70 to 75°C and they fully open at 82°C. High temperature thermostats, with permanent anti-freezesolutions(Prestine,Zerex,etc.),startopeningat80to90°C

andfullyopenat92°C.

Typesofthermostat

Therearethreetypesofthermostats:(i)bellowtype,(ii)bimetallictype and (iii) pellettype.

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 andcontracts whencooled.Thepelletis connectedtothevalvethrougha piston, such that on expansion of the
pellet, it opens the valve. A coil spring closes the valve when the pellet contracts.

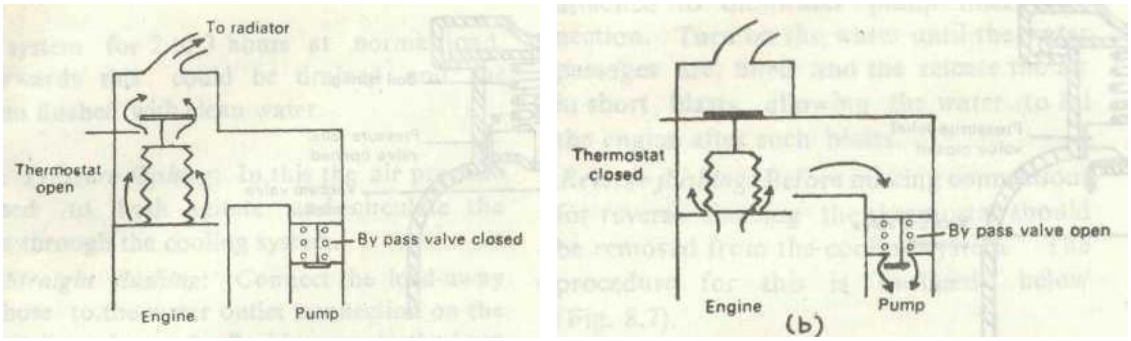
PRESSURECOOLINGSYSTEM

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 waterincreases.The higher watertemperature givesmore 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 and13 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 releasedbythepressure 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-FREEZESOLUTIONS

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, mixturesofalcoholandglycerineandvariousmixturesofotherchemicals.

SERVICING&CLEANINGOFCOOLINGSYSTEM

For smooth and trouble-free service, the cooling system should be cleanedatperiodic intervals topreventtheaccumulationofexcessiverust 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.

CoolingSystemCleaningProcedure

Itinvolvesthefollowingsteps.

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 upthis solutioninthe radiator andengine block andrun theengine on idle load for 8 to 10 hours. Drain this solution and flush the system

withcleanwater.

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. Followthe same procedure.

LUBRICATIONSYSTEM

IC. engine is made of many moving parts. Due to continuousmovement 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.

PURPOSEOFLUBRICATION

Lubrication produces the following effects: (a) Reducing friction effect (b) Coolingeffect(c)Sealingeffectand(d)Cleaningeffect.

(a) Reducingfrictional effect:Theprimarypurposeofthelubricationis 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

producedbythemovementoftwometalsurfacesovereachother.

(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: Accordingtothis theory,thelubricant is, supposedtoactlikemassofglobules,rollinginbetweentwosurfaces.It produces a rolling effect, which reduces friction.

(ii) Boundary layer theory: According to this theory, the lubricant is soaked in rubbing surfaces and formsoilysurface over it. Thus the slidingsurfacesarekeptapartfromeachother,therebyreducingfriction.

TYPESOF LUBRICANTS

Lubricants are obtained from animal fat, vegetables and minerals Lubricants made of animal fat, does not stand much heat. It becomes waxyand gummy which is not verysuitable 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. Itshouldhavesufficientviscositytokeeptherubbingsurfaces apart
2. Itshouldremainstableunderchangingtemperatures.
3. Itshouldkeeplubricatedpansclean.
4. Itshouldnotcorrodemetallicsurfaces.

ENGINELUBRICATINGSYSTEM

Thelubricating system of an engineis anarrangement 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)waterpumpand(viii)ignitionmechanism.

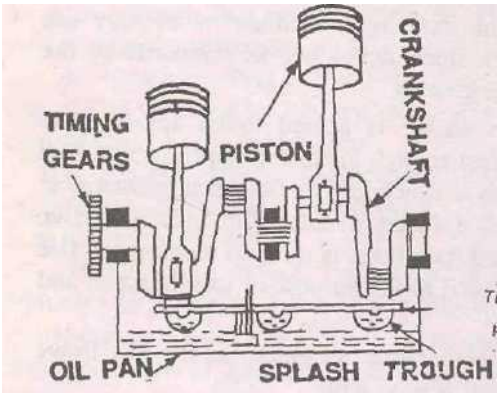
There are three common systems of lubrication used on stationary engines, tractor engines andautomobiles:

(i)Splashsystem(ii)Forcedfeedsystemand(iii)Combinationofsplash

andforcedfeedsystem.

SPLASHSYSTEM

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.



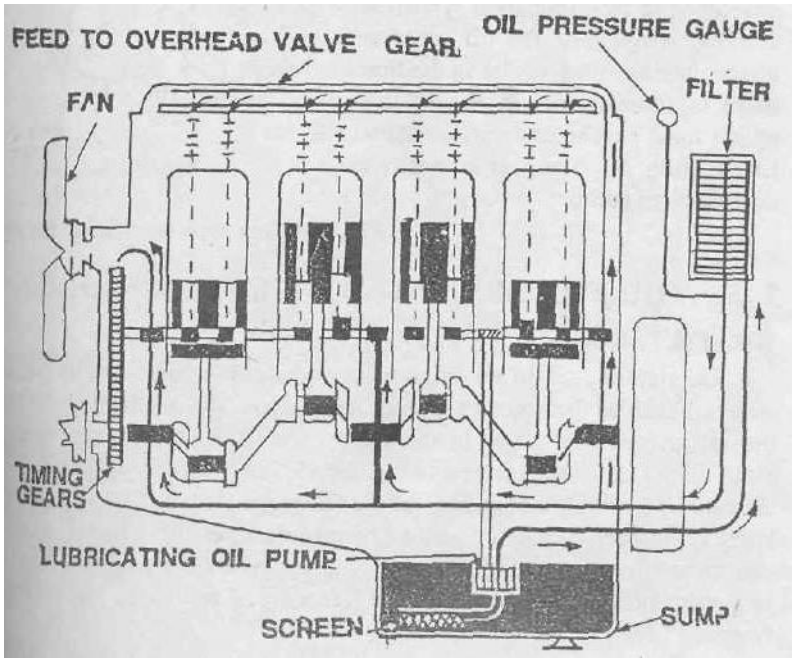
Splashlubricationsystem

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 holesand 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.

FORCEDFEEDSYSTEM

Inthis system,theoil is pumpeddirectlylothecrankshaft,connecting rod, pistonpin,timinggearsandcamshaft oftheenginethroughsuitable paths

ofoil.Usuallytheoilfirstentersthemaingallery,whichmaybeapipeora 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, pistonsand 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.

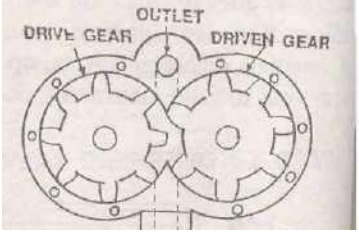


Forcedfeed lubricationsystem

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.

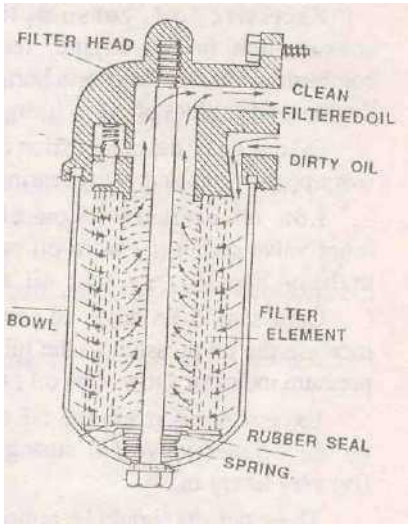
COMBINATION OFSPLASHANDFORCEDFEEDSYSTEM Inthis system, the engine component, which are subjected to very heavy load are lubricated under forced pressure,such as main bearing connecting rod bearing and camshaft bearing. The rest of the partslike cylinder liners,cams,tappetsetcarelubricatedbysplashedoil.

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 oftheengine.Anoilpressuregaugefittedinthe



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 dirtyelements of the oil in an effective way. Itis 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 usuallyfitted 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 offilter,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 pressureintheoillines.Itservestowarntheoperatorofanyirregularityin the system.

Crankcase breather: The engine crankcase is always fitted with some kindof breather, connecting thespace 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.

TROUBLESINLUBRICATIONSYSTEM

There are a few common troubles in lubrication system such as: (1) Excessiveoilconsumption(2)Lowoilpressureand(3)Excessiveoil pressure-

Excessiveoilconsumption:Whenthereisexcessiveoilconsumptionin theengine,thereasonsarc:(a)moreoilgoestocombustionchamber and gets burnt (b) some leakage occurs in some part of - the line and (c) lossofoil informofvapourthrough ventilatingsystem.Oil canenter thecombustionchamberthroughringsandcylinderwalls,wornpiston rings and worn bearings.

Low oilpressure: Low oil pressure canresult due to: (i) weak reliefvalve spring (ii)wornoil pump (iii)cracked oil line (iv)obstructionintheoillines (v)verythinoiland(vi)wornoutbearings.

Care should be taken to remove these defects as far as possible to increasetheoilpressureinthelubricatingsystem.Sometimesdefectiveoil 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 valvespring(iii)clogged oillineand(iv)very heavy oil.

Thesedefectsshouldberemoved toreduce the excessive oilpressurein thelubricatingsystem.Sometimesdefectiveoilpressureindicatorrecords high oil pressure. Care should be taken to check this defect.

CAREANDMAINTENANCEOFLUBRICATIONSYSTEM

Thefollowingarefewsuggestionsforgoodlubricationsystem:

- Agooddesignofoilcirculationsystemshouldbechosen.
- Correctgradeoflubricantensureslongandtroublefreeservice.
- Oilshouldbemaintainedatdesiredlevelintheoilchamber.
- Oilshouldbecleanedregularlyand afterspecified periodofuse, old filters should be replaced bynew filters.
- Connections,pipings,valvesandpressuregaugeshouldbe checked regularly.
- Oil should be changed regularly after specified interval of time. Beforeputtingthenewoil,thecrankcase shouldbecleaned and flushed well with a flushing oil.
- Precautionsshouldbetakentokeeptheoilfreefromdustand water.

HybridElectricalVehicles

Introduction

A hybrid electric vehicle (HEV) has two types of energystorage units, electricityandfuel.Electricitymeansthatabattery(sometimes assisted byultracaps)is usedtostorethe energy, andthatan 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,fromnowoncalled*engine*)isusedtogenerate 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 electromotoronly. Inthefirstcase,thevehiclewillhavebothanengine 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 onthe 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 pneumaticpower,andhumanpower.Inthefirstcase,theICEisa spark ignition engines (gasoline) or compression ignition direct injection (diesel) engine. In the first two cases, the energy conversionunitmaybepoweredbygasoline,methanol, compressed natural gas, hydrogen, or other alternative fuels.

Motorsarethe"workhorses"ofHybridElectricVehicledrivesystems. The electric traction motor drives the wheels of the vehicle. Unlike a traditionalvehicle,wheretheenginemust"rampup"beforefulltorque can be provided, an electric motor provides full torque at lowspeeds.
The motor also has low noise and high efficiency. Other characteristics includeexcellent"offtheline"acceleration,gooddrive control,goodfault tolerance and flexibility in relation to voltage fluctuations.
Thefront-runningmotortechnologiesforHEVapplicationsinclude PMSM(permanent magnetsynchronousmotor),BLDC(brushless DC motor), SRM (switched reluctance motor) and AC induction motor.
Amainadvantageofanelectromotoristhepossibilitytofunctionas generator.InallHEVsystems,mechanicalbrakingenergyis regenerated. Themax.operationalbrakingtorqueislessthanthemaximum

tractiontorque;thereisalwaysamechanicalbrakingsystem integrated in a car.

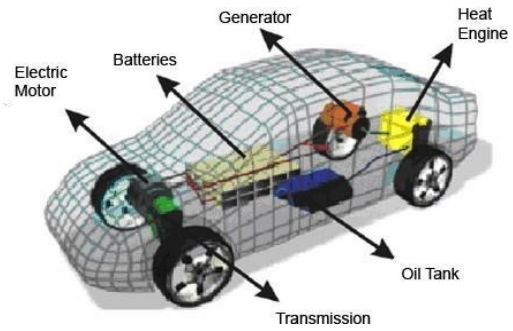
The battery pack in a HEV has a much higher voltage than the SIL automotive12Voltsbattery,inordertoreducethecurrentsandtheI^2R losses.

Accessoriessuchaspowersteeringandairconditioningarepowered byelectricmotorsinstead of being attached to thecombustion engine. Thisallowsefficiencygainsastheaccessoriescanrunataconstant speed or can be switched off, regardless of how fast the combustion engine is running.
Especiallyinlonghaultrucks,electrical powersteeringsaves alotof energy.

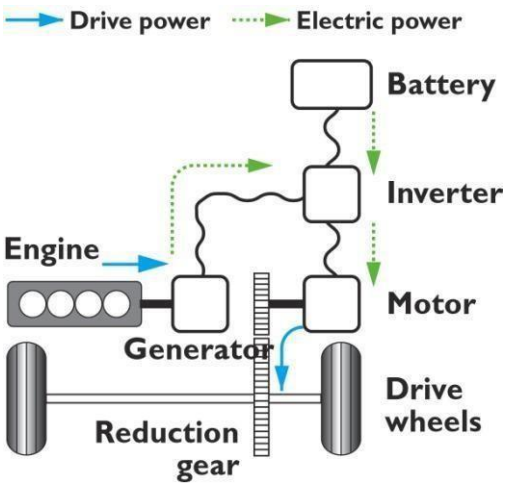
1. Typesbydrivetrainstructure

Serieshybrid

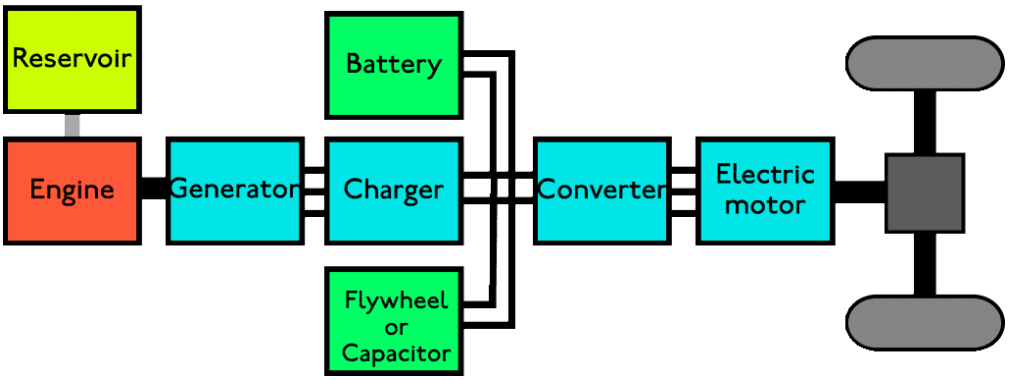
In a series hybrid system, the combustion engine drives an electric generator (usually a three-phase alternator plus rectifier) instead of directly driving the wheels. The electric motor is the only means of providingpowertothewheels.Thegeneratorbothchargesabatteryand powers an electric motor that moves the vehicle. When large amounts of powerarerequired,themotordrawselectricityfromboththebatteriesand the generator.



Serieshybridconfigurationsalreadyexistalongtime:diesel-electric locomotives, hydraulic earthmoving machines, diesel-electric power groups, loaders.



Structure ofa series hybrid vehicle (belowwithflywheelorultracapsas peak power unit)



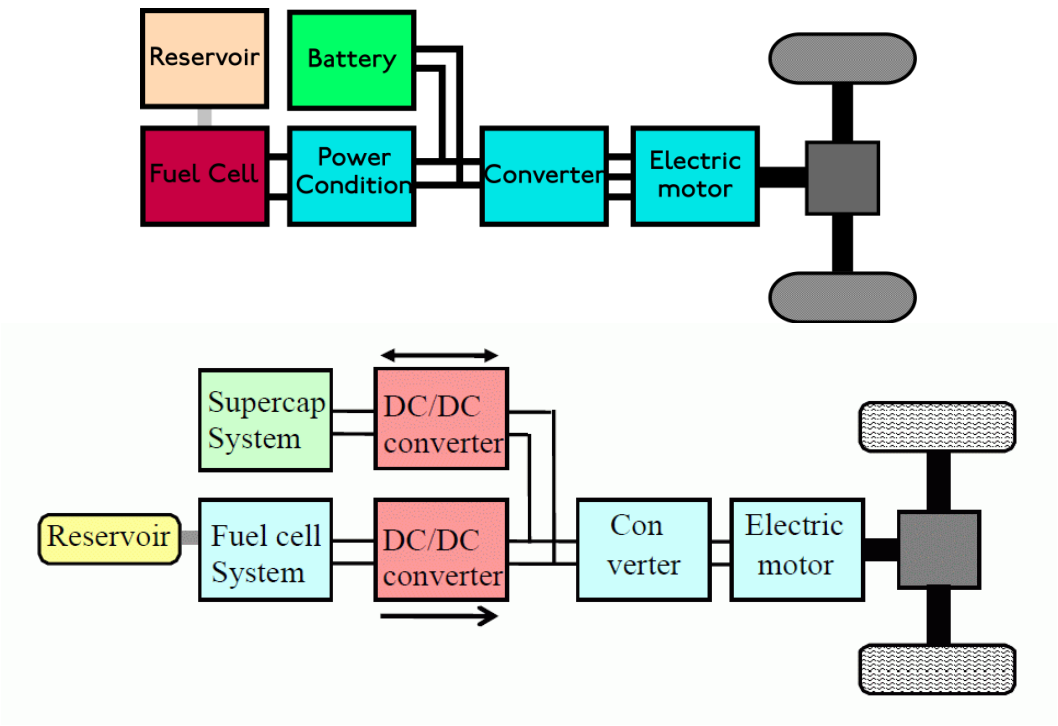
Series hybrids can be assisted by ultracaps (or a flywheel: KERS=Kinetic Energy Recuperation System), which can improve the efficiency by minimizing the losses in the battery. They deliver peak energyduringaccelerationandtakeregenerativeenergyduringbraking. Therefore, the ulracaps are kept charged at 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 electricmotorsareefficientoverawidespeedrange.Ifthemotorsare attached to the vehicle body, flexible couplings are required.

Some vehicle designs have separate electric motors for each wheel. Motorintegrationintothe wheels has thedisadvantagethattheunsprung mass increases, decreasing ride performance. Advantages of individual wheel motors include simplified traction control (no conventional mechanicaltransmissionelementssuchasgearbox,transmissionshafts, differential),allwheel drive,and allowinglowerfloors,whichis usefulfor

buses.Some8x8all-wheeldrivemilitaryvehiclesuseindividual wheel motors.

Afuelcellhybridelectricalwayshasaseriesconfiguration:the engine-generatorcombinationisreplacedbyafuelcell.



Structuresofafuelcellhybridelectric vehicle

Weaknessesofserieshybridvehicles:

- TheICE,thegeneratorandtheelectricmotoraredimensionedto handlethefullpowerofthevehicle.Therefore,thetotalweight, 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,thetotalefficiencyisinferiortoaconventionaltransmission, due to the several energy conversions.

Advantagesofserieshybridvehicles:

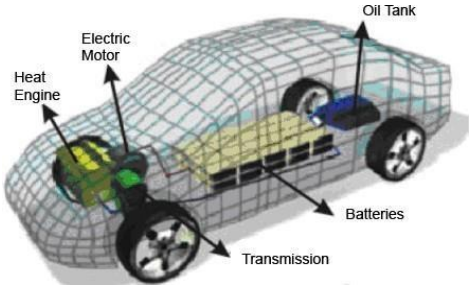
- Thereisnomechanicallink betweenthecombustionengine andthewheels.Theengine-generatorgroupcanbelocated everywhere.
- Therearenoconventionalmechanicaltransmissionelements (gearbox, transmission shafts).
  Separateelectric wheelmotorscanbeimplementedeasily.
- Thecombustionenginecanoperateinanarrowrpm range(its mostefficientrange),evenasthecarchangesspeed.

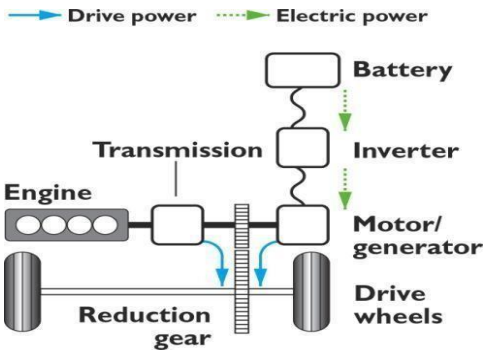
- Serieshybridsarerelativelythemostefficientduringstop-and-go city driving.

ExampleofSHEV:RenaultKangoo.

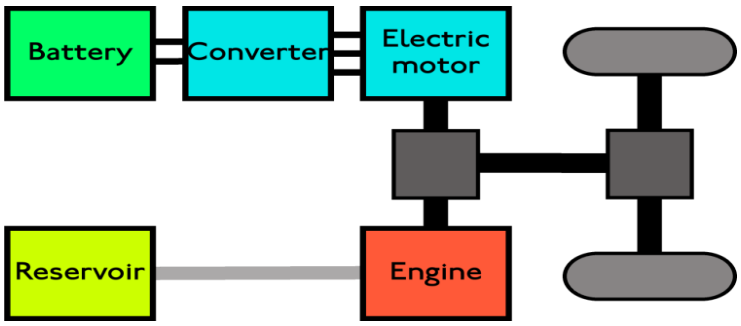
Parallelhybrid

Parallelhybridsystemshavebothan internalcombustionengine (ICE) and an electricmotor inparallel connected to amechanical transmission.





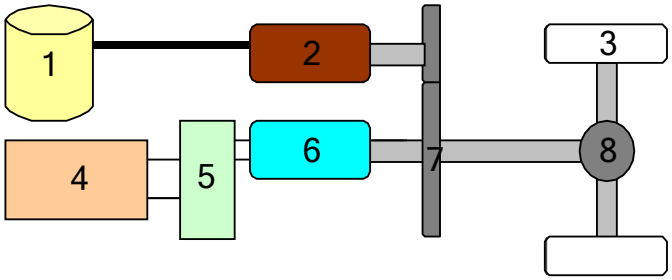
Structureofaparallelhybridelectric vehicle



Most designscombine alargeelectrical generator and amotor intoone unit,oftenlocatedbetweenthecombustionengineandthetransmission, replacing both the conventional starter motor and the alternator (see

figures above). The battery can be recharged during regenerative breaking,anddduringcruising(whentheICEpowerishigherthanthe required power for propulsion). As there is a fixed mechanical link betweenthe wheelsandthe motor(no clutch),the batterycannot be charged when thecar isn't moving.

When the vehicle is using electrical traction power only, or during brake whileregeneratingenergy,the ICEisnotrunning(itisdisconnectedbya clutch) or is not powered (it rotates in an idlingmanner).



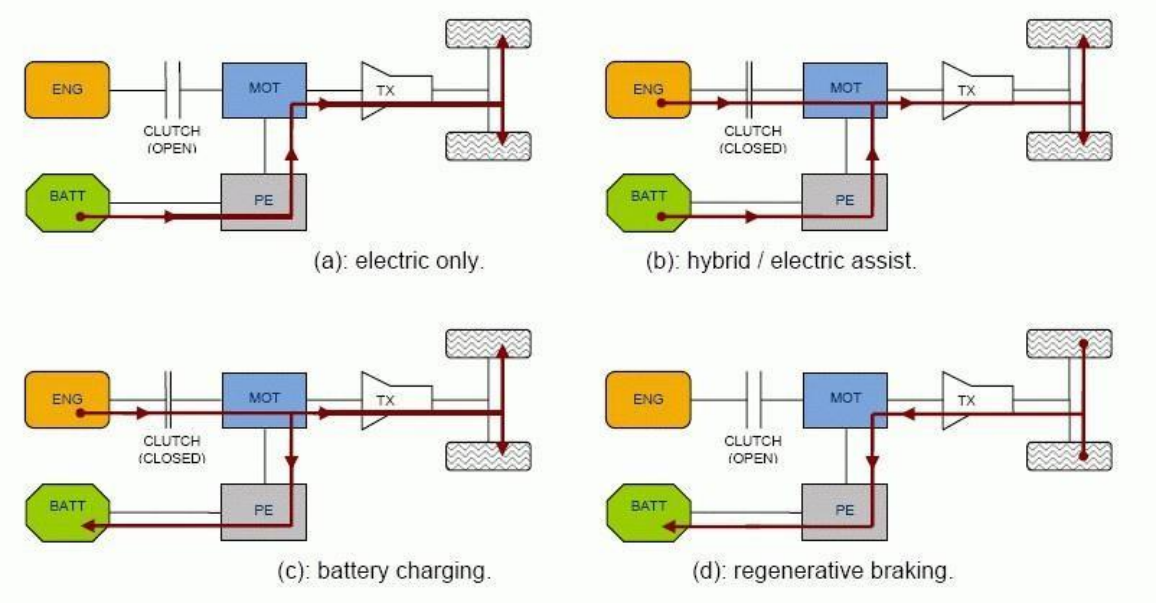
1:Fueltank
2: Engine
3:Wheels
4:Battery
5:Converter
6:ElectricMotor
7:Reductiongear
8:Differential

$$\omega_8 = \omega_6 = \omega_2 / x2$$

$$T8 = \frac{T_6}{\eta_6} + \frac{x_2 T_2}{\eta_2}$$

Operationmodes:

Theparallelconfigurationsupportsdiverseoperatingmodes:



Sometypicalmodesforaparallel hybridconfigurationPE=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 rechargedbytheICE.Thisistheusual wayofoperatingaroundthecity, as well as in reverse gear, since during reverse gear the speed is limited.

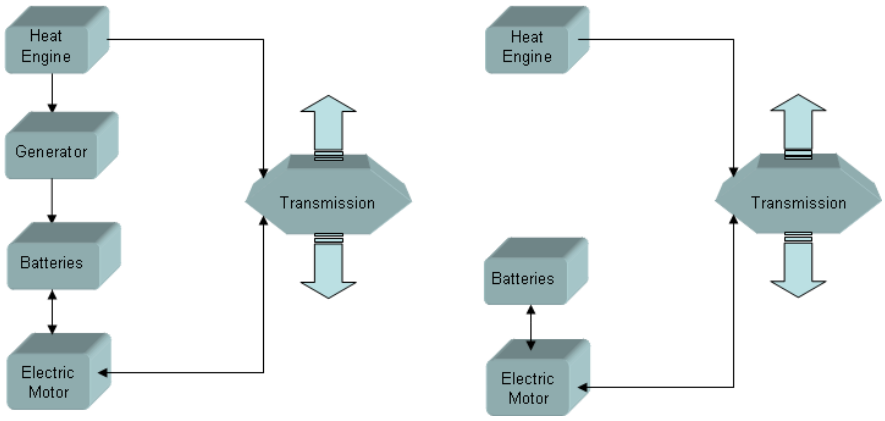
(b) ICEpoweronly:Atspeedssuperiorto40km/h,onlytheheatengine operates. This is the normaloperating way at the road.

(b) ICE + electric power: if more energy is needed (during acceleration orathigh speed), the electricmotor startsworkingin parallel tothe heat engine, achieving greater power

(c) ICE+ batterycharging:iflesspoweris required,excessofenergyis usedtochargethebatteries.Operatingtheengineathighertorquethan necessary, it runs at a higher efficiency.

(d) regenerative breaking: While braking or decelerating, the electric motortakesprofit of the kineticenergyofthe 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.



AparallelHEVcan haveanextra generator forthebattery(left)Withoutgenerator,the motor will charge the battery (right)

Weaknesses of parallelhybrid vehicles:

- Rathercomplicated system.
- TheICE doesn'toperateinanarroworconstantRPMrange, thus efficiency drops at lowrotation speed.
- Asthe ICEisnotdecoupledfromthewheels,thebatterycannotbe charged at standstill.

Advantagesofparallelhybridvehicles:

- Total efficiencyis higher during cruising and long-distance highway driving.
- Large flexibility to switch between electric and ICE power
- Comparedtoserieshybrids,theelectromotorcanbedesigned lesspowerfulthantheICE,asitisassistingtraction.Onlyone electrical motor/generator is required.

ExampleofPHEV:

HondaCivic.Honda'sIMA(IntegratedMotorAssist)usesarather traditional ICE with continuouslyvariable transmission, where the flywheel is replaced with an electric motor.

Influenceofscale: aVolvo 26 ton truck (12 tonown weight,14tonmax

load)equippedwith200kgofbatteriescandriveonpureelectricpower

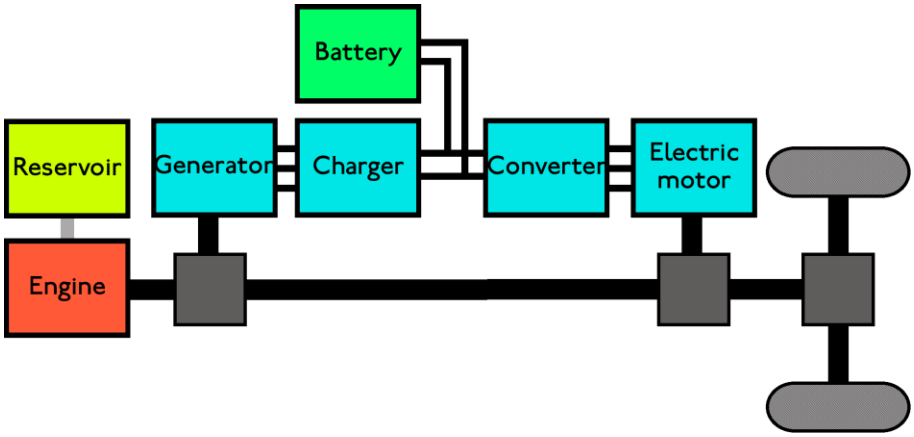
for2minutesonly! Becauseofspaceconstraints,itisnotpossibleto build in more batteries.

BMW7SeriesActiveHybrid.

Combinedhybrid

Combinedhybridsystemshavefeaturesofbothseriesandparallel hybrids.Thereis a *doubleconnection betweenthe engineand the driveaxle:mechanicalandelectrical*.Thissplitpowerpathallows interconnecting mechanical and electrical power, at some cost in complexity.

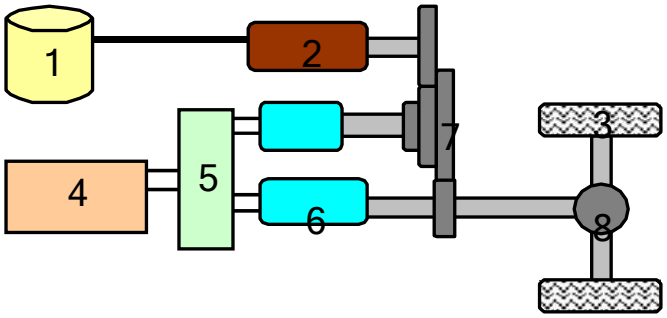
Power-splitdevicesareincorporatedinthepowertrain.Thepowertothe wheels can be either mechanical or electrical or both. This is also the caseinparallelhybrids.Butthemainprinciplebehindthecombined system is the *decoupling of the power supplied by the engine from the power demanded by the driver*.



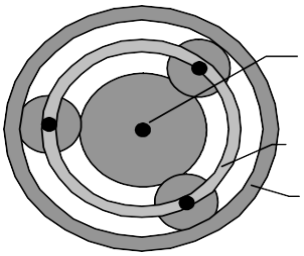
Simplifiedstructureofacombinedhybridelectric vehicle

Inaconventionalvehicle,alargerengineisusedtoprovideacceleration from standstill than one needed for steady speed cruising. This is becauseacombustionengine'storqueisminimalatlowerRPMs,asthe engineis its own air pump.Ontheotherhand,anelectricmotor 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 muchsmaller role.

At lower speeds, this system operates as a series HEV, while at high speeds,wheretheseriespowertrainislessefficient,theenginetakes over.Thissystemismoreexpensivethanapureparallelsystemasit needs an extragenerator, amechanicalsplit powersystem andmore computing power tocontrol the dual system.



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



S: sun

$+\rho \cdot \omega = \omega + \rho \cdot \omega$

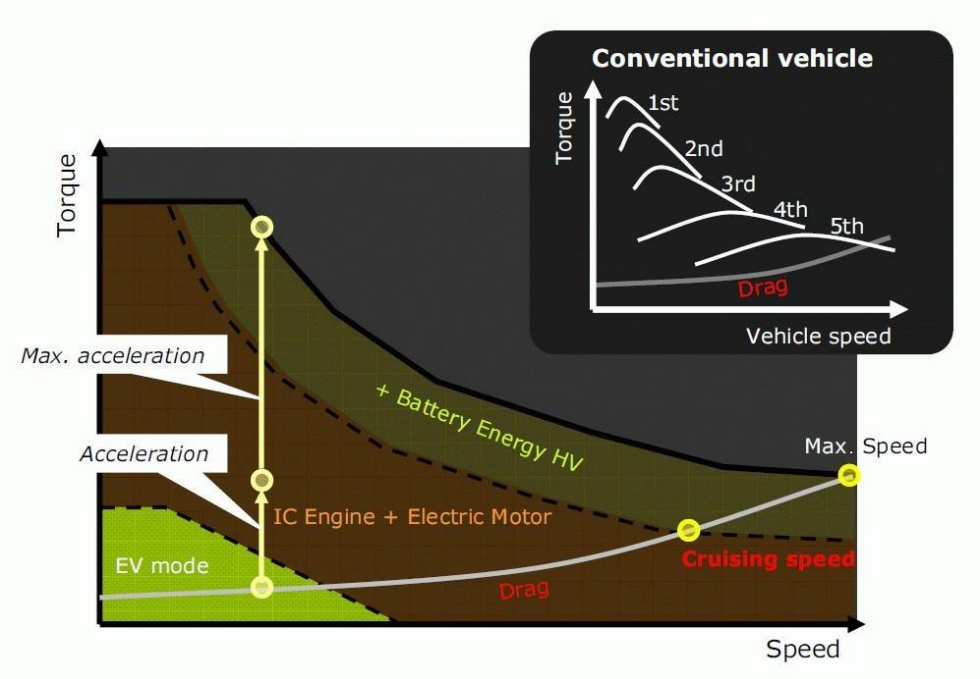
$\rho =$ (1) C S R

C: carri er

z_R / z_S

R:ring

Combined HEV with planetaryunitasusedin the Toyota Prius



Combinedhybriddrivemodes

Weaknessesofcombinedhybridvehicles:

- Verycomplicatedsystem,moreexpensivethanparallelhybrid.
- The efficiencyof the power train transmission is dependent on the amount of power being transmitted over the electrical path, asmultipleconversions,eachwiththeirownefficiency,leadtoa lower efficiency of that path (~70%) compared with the purely mechanical path (98%).

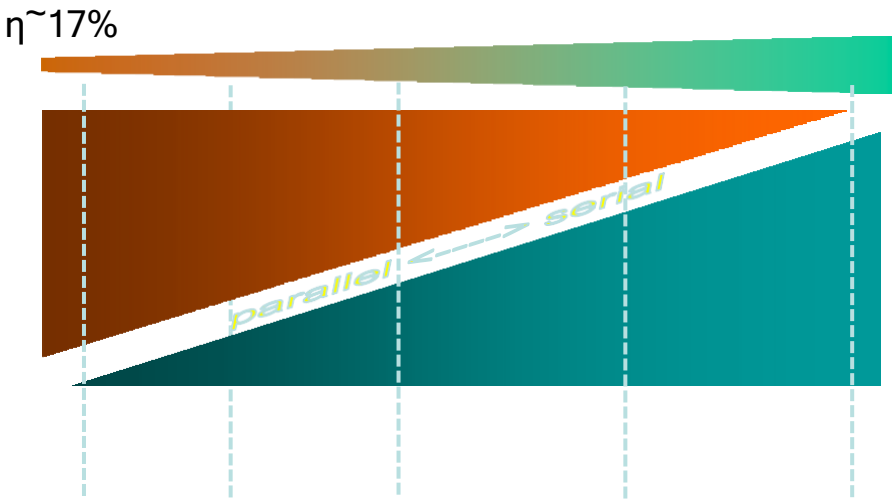
Advantagesofcombinedhybridvehicles:

- MaximumflexibilitytoswitchbetweenelectricandICEpower
- Decoupling of the power supplied by the engine from the powerdemandedbythe driverallows for a smaller, lighter,and more efficient ICE design.

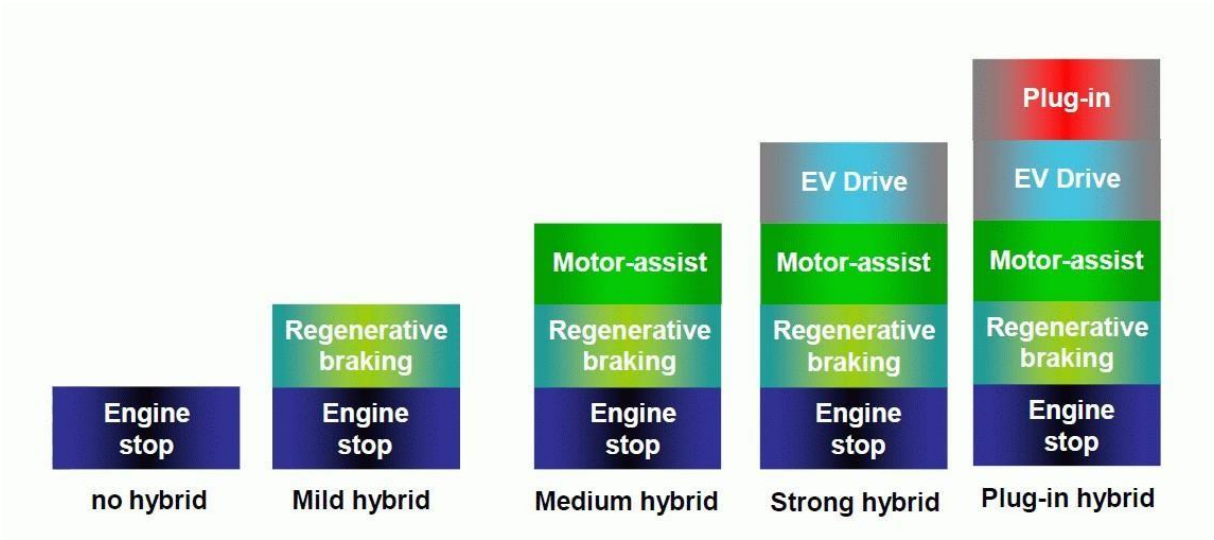
ExampleofCHEV:ToyotaPrius,Auris, LexusCT200h,LexusRX400h.

2. Typesbydegreeofhybridization

Parallelandcombined hybrids can becategorized depending upon how balancedthedifferentportionsareatprovidingmotivepower.Insome cases,thecombustionengineisthedominantportion;theelectricmotor turns on only when a boost is needed. Others can run with just the electric system operating.



Con-ventional Vehicle	Micro-HEV e.g. BMW 1er „Stop& Start“	Medium/ mild-HEV e.g. Citroen C4HDi	Full-HEV e.g. Toyota Prius, Auris	Plug-In HEV e.g. Volvo C30 Concept	Electric Vehicle	



OverviewofHybrid-powertrain concepts

Stronghybrid(=full hybrid)

A full hybrid EV can run on just the engine, just the batteries, or a combinationofboth.Alarge,high-capacitybatterypackisneeded for battery-only operation.

<u>Examples:</u>

The ToyotaPrius, Auris and Lexus are full hybrids, as these cars can bemovedforward onbatterypower alone.TheToyotabrand name for this technology is Hybrid Synergy Drive. A computer oversees operation ofthe entire system,determiningifengine ormotor,orboth shouldberunning.TheICEwillbeshutoffwhentheelectricmotoris sufficient to provide the power.

Mediumhybrid(=motorassisthybrid)

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, andthisisnotastandardmode.Comparedtofull hybrids,theamountof 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"stepsonthegas"andrequiresextrapower.Theelectricmotor may also be used to re-start the combustion engine, deriving the same benefitsfromshuttingdownthemainengineatidle,whiletheenhanced 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 thevehiclesolelyonelectricpowerduringmediumspeedcruising.

Avariationonthistypeofhybridis theSaturnVUE GreenLinehybrid systemthatusesasmallerelectricmotor(mountedtothesideofthe engine),andbatterypackthantheHondaIMA,butfunctionssimilarly.

Anothervariationonthistypeis Mazda'se-4WDsystem,offeredonthe MazdaDemiosoldinJapan.Thisfront-wheeldrivevehiclehasan 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.

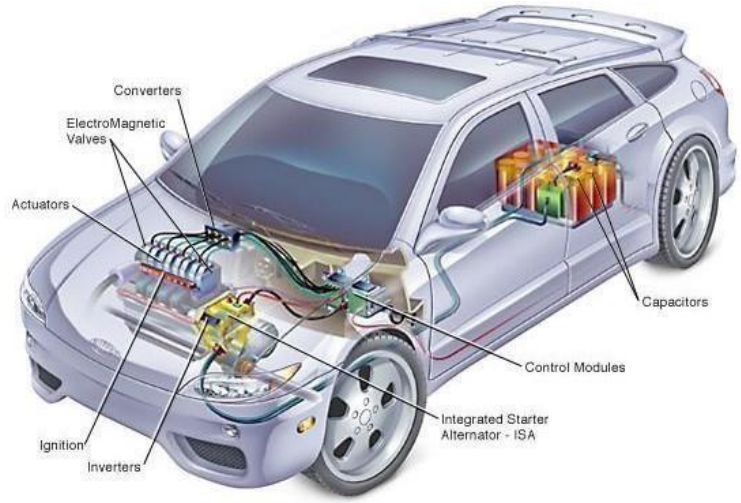
Mildhybrid/microhybrid(=start/stopsystemswithenergy recuperation)

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 quicklyand 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 uniqueto hybrids;Subarupioneeredthisfeatureintheearly1980s,and the Volkswagen Lupo 3L is one example of a conventional vehicle that shuts off its engine when at astop.

Asinotherhybriddesigns,themotoris usedforregenerativebrakingto recaptureenergy.Butthereisnomotor-assist, andnoEVmode atall. Therefore,manypeopledonotconsiderthesetobehybrids,sincethere 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 uponstartup that the majority of engine wear occurs, thefrequent 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.



PowertrainofamildHEV

Examples:

BMW succeededincombiningregenerativebrakingwiththemildhybrid "start-stop" system in theircurrent 1-series model.

Citroënproposesastart-stopsystem onitsC2andC3models. The concept-carC5Airscapehasanimprovedversionofthat,adding regenerative breaking and traction assistance functionalities, and supercapacitors for energy buffering.

Plug-inhybrid(=gridconnectedhybrid=vehicletogridV2G)

All the previous hybrid architectures could be grouped within a classification of *charge sustaining*: theenergy 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,theSOCofenergystoragesystem willmoreorless returntoits 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 batteriesandtheabilityto recharge from theelectricpowergrid.Theirmainbenefitisthattheycanbegasoline-

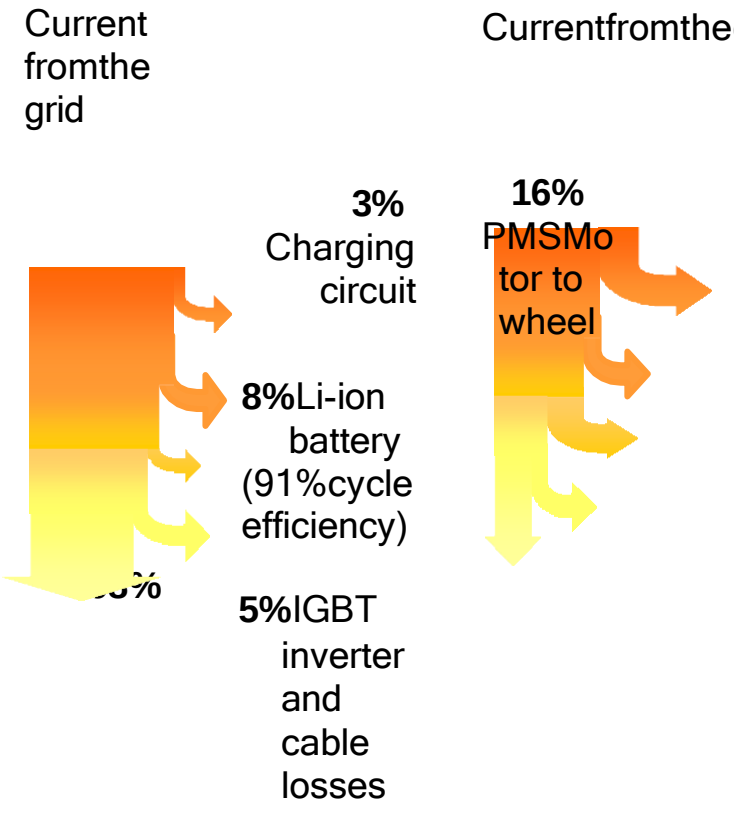
independent for daily commuting, but also have the extended range of a hybrid for long trips.

Gridconnectedhybridscanbedesignedas *chargedepleting*:partof the “fuel”consumedduringadriveis delivered bytheutility,bypreferenceat night. Fuel efficiency is then calculated based on actual fuel consumed bythe ICE andits gasolineequivalent ofthekWhofenergydelivered by the utility during recharge. The "well-to-wheel" efficiency and emissions ofPHEVscomparedtogasolinehybridsdependsontheenergysources used for the grid utility (coal, oil, natural gas, hydroelectric power, solar power, wind power, nuclear power).

InaserialPlug-Inhybrid,the ICEonlyservesforsupplyingtheelectrical power via a coupled generator in case of longer driving distances. Plug inhybridscanbemademulti-fuel,withtheelectricpowersupplemented 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 automobileindustry.Plug-invehicleswhichusebatteriestostoreelectric energy*outperform*carswhichusehydrogenascarrierfortheenergy taken from the grid. The following figures indicate the efficiencies of a hydrogen fuel cell HEV and a battery powered EV.



TractionpowerefficiencyofapluggedEV.
LeftabatterypoweredplugIn EV(MitsubishiLancerEvolution MIEV))RightaFuelCell EV (Mercedes NECAR 3)

For typical driving cycles, the achieved efficiencies are lower. The battery powered EV achieves efficiencies in therangeof50to60%.ThehydrogenpoweredEVhasatotalefficiencyofabout13%onlyatthosedrivecycles.

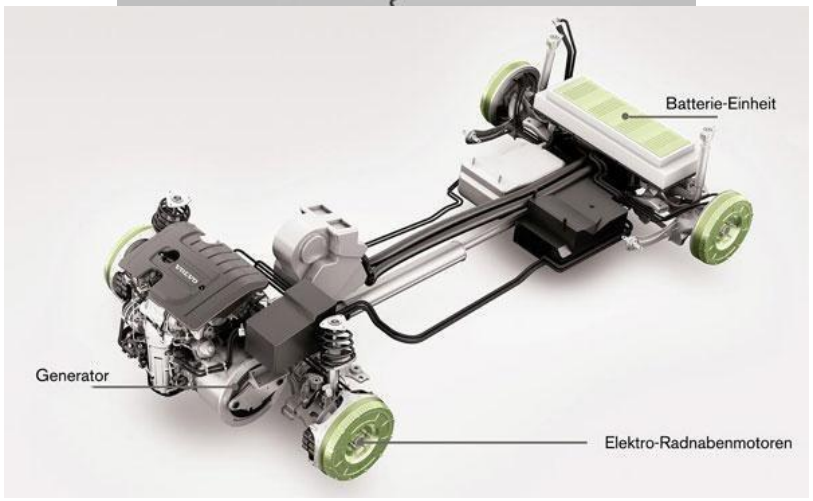
Examples:

MercedesBlueZEROE-CELLPLUS(conceptcar):seriesHEV.OpelAmpera:series HEV.

Plug-in-HybridOpelAmpera

ThePlug-in-HybridVolvoC30(conceptcar)isaseriesHEV.Ithasa1,6litergasoline/bio-ethanolICE.A synchronousgeneratorchargestheLi-polymerbattery(ca.100kmautonomy) whenthebatterySoCislower

than30%.Therearefourelectricwheel-motors.



Plug-in-HybridVolvo C30

3. Typesbynatureofthepowersource

Electric-internalcombustionenginehybrid

Therearemanywaystocreateanelectric-internalcombustionhybrid.Thevarietyofelectric-ICEdesignscanbe

differentiatedbyhowtheelectricandcombustionportionsofthepowertrainconnect(series,parallelor combined),at whattimes eachportionisinoperation,andwhatpercentofthepowerisprovidedbyeachhybrid component. Manydesigns shutoffthe internalcombustion enginewhen itis not needed inordertosave energy, see 2.3.

Fuelcellhybrid

Fuelcell vehicleshaveaserieshybridconfiguration.Theyareoftenfittedwithabatteryorsupercapacitorto deliverpeakaccelerationpowerandtoreducethesizeandpowerconstraintsonthefuelcell(andthusitscost). See 1.1.

Humanpowerandenvironmentalpowerhybrids

Manylandandwatervehiclesusehumanpowercombinedwithafurtherpowersource.Commonareparallel hybrids, e.g.aboatbeingrowedandalsohavingasailset,or motorizedbicycles.Alsosomeserieshybridsexist. 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.

Thefollowingexamplesdon't useelectricalpower,butcanbeconsideredashybridsaswell:

Pneumatichybrid

Compressed air can also power a hybrid car with a gasoline compressor to provide the power. Moteur DeveloppementInternationalinFranceproducessuchaircars.AteamledbyTsu-Chin Tsao,aUCLAmechanical 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 vehiclein that braking energyis harnessed and stored to assist the engine as needed during acceleration.

Hydraulichybrid

A hydraulic hybrid vehicle uses hydraulic and mechanical components instead of electrical ones. A variable displacementpumpreplacesthemotor/generator,andahydraulicaccumulator(whichstoresenergyashighly

compressednitrogengas)replacesthebatteries.Thehydraulicaccumulator,which isessentiallyapressuretank, is potentially cheaper and more durable than batteries. Hydraulic hybrid technology was originally developed by Volvo Flygmotor and was used experimentallyin buses fromthe early1980s andis still an active area.

Initial conceptinvolveda giant flywheel (see Gyrobus)forstorageconnectedto ahydrostatic transmission,butit was later changed to a simpler system using a hydraulic accumulator connected toa hydraulic pump/motor. It is also being actively developed by Eaton and several other companies, primarily in heavy vehicles like buses, trucksandmilitaryvehicles.AnexampleistheFordF-350MightyTonkaconcepttruck shownin2002.Itfeatures an Eaton system that can accelerate the truck up to highwayspeeds.