Vikash Polytechnic, Bargarh
Vikash Polytechnic
Campus: Vikash Knowledge Hub, Barahaguda Canal Chowk, NH6 PO/DIST: Bargarh-768028, Odisha

Lecture Note on

Automobile Engineering & Hybrid Vehicle(AE&HV)

Of Mechanical Engineering

Diploma 6th Semester

Submitted By:- Mr. Debraj Mishra

TH.2 AUTOMOBILE ENGINEERING AND HYBRID VEHICLES

Name of the Course: Diploma in MECHANICAL ENGINEERING			
Course code:		Semester	6th
Total Period:	60	Examination	3 hrs
Theory periods:	4 P/W	Internal assessment	20
Maximum marks:	100	End Semester Examination:	80

A. RATIONALE:

Automobiles are the principal mode of transport system. Their manufacture and maintenance gives a major scope for employment. Many entrepreneur pass outs go for servicing of automobiles or trading/ manufacturing of auto components. Thus automobile engineering is an important subject to be in the regular curriculum of the mechanical engineering.

B. COURSE OBJECTIVES:

At the end of the course the students will be able to:

- Understand automobile chassis, transmission, breaking and fuel system etc.
- Understand the basics of electric vehicle kinematics.
- Understand the concepts of hybrid electric vehicles.

C.TOPIC WISE DISTRIBUTION OF PERIODS

Sl No.	Topic	Periods
1	Introduction & Transmission System	12
2	Braking system	5
3	Ignition & Suspension System	10
4	Cooling and Lubrication	8
5	Fuel system	10
6	Hybrid and Electric Vehicles	15

C.COURSE CONTENTS

1.0 INTRODUCTION & TRANSMISSION SYSTEM:

1.1 Automobiles: Definition, need and classification: Layout of automobile chassis with major components (Line diagram)
1.2 Clutch System: Need, Types (Single & Multiple) and Working principle with sketch
1.3 Gear Box: Purpose of gear box, Construction and working of a 4 speed gear box
1.4 Concept of automatic gear changing mechanisms
1.5 Propeller shaft: Constructional features
1.6 Differential: Need, Types and Working principle

2.0 BRAKING SYSTEM:

2.1 Braking systems in automobiles: Need and types
2.2 Mechanical Brake
2.3 Hydraulic Brake
2.4 Air Brake
2.5 Air assisted Hydraulic Brake
2.6 Vacuum Brake

3.0 IGNITION & SUSPENSION SYSTEM:

3.1 Describe the Battery ignition and Magnet ignition system

3.2 Spark plugs: Purpose, construction and specifications

3.3 State the common ignition troubles and its remedies

3.4 Description of the conventional suspension system for Rear and Front axle

3.5 Description of independent suspension system used in cars (coil spring and tension bars)

3.6 Constructional features and working of a telescopic shock absorber

4.0 COOLING AND LUBRICATION:

4.1 Engine cooling: Need and classification

4.2 Describe defects of cooling and their remedial measures

4.3 Describe the Function of lubrication

4.4 Describe the lubrication System of I.C. engine

5.0 FUEL SYSTEM:

5.1 Describe Air fuel ratio

5.2 Describe Carburetion process for Petrol Engine

5.3 Describe Multipoint fuel injection system for Petrol Engine

5.4 Describe the working principle of fuel injection system for multi cylinder Engine 5.5 Filter for Diesel engine

5.6 Describe the working principle of Fuel feed pump and Fuel Injector for Diesel engine

6.0 ELECTRIC AND HYBRID VEHICLES:

6.1 Introduction, Social and Environmental importance of Hybrid and Electric Vehicles

6.2 Description of Electric Vehicles, operational advantages, present performance and applications of Electric Vehicles

6.3 Battery for Electric Vehicles, Battery types and fuel cells

6.4 Hybrid vehicles, Types of Hybrid and Electric Vehicles: Parallel, Series, Parallel and Series configurations;6.5 Drive train

6.6 Solar powered vehicles

D.SYLLABUS COVERED UP TO I.A-CHAPTERS 1,2 &3

E.LEARNING RESOURCES:

Sl. No.	***Name of Authors***	***Title of the Book***	***Name of the Publisher***
1	R.B.Gupta	Automobile Engineering	Satya Prakashan
2	Dr Kirpal Singh	Automobile Engineering Vol- I & II	Standard Publishers
3	C.P.Nakra	Automobile Engineering	Dhanpat Rai Publication
4	W.H.Course	Automotive Engine	McGraw Hill
5	Iqbal Hussain	Electric & Hybrid Vehicles – Design Fundamentals	CRC Press, 2
6 A.K. Babu		Statistical Electric & Hybrid Vehicles	Khanna Publishing House, New Delhi, 2018

1.1 Automobile

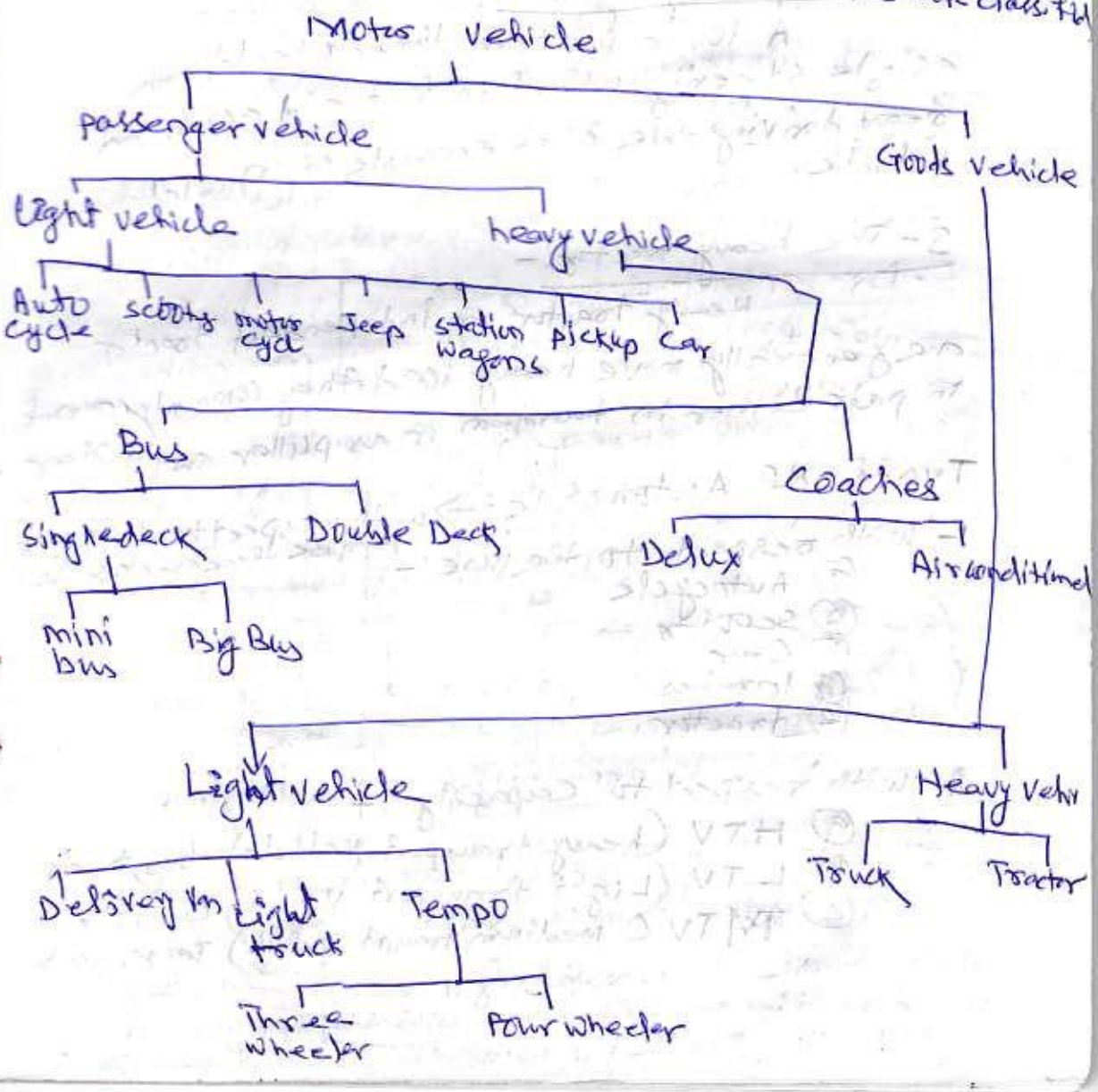
Definition :-

Present is the age of Automobile or self-propelled vehicles. A vehicle producing power within itself for its propulsion is known as self propelled vehicle

A self propelled vehicle used for transportation of goods and passengers on the ground is called automobile. Automobiles or Automotive means a vehicle which can move by itself.

Need and classification :->

As per our need motor vehicles are classified



Classification :→

In general Three main types of classification of vehicle

1- The single-unit vehicle or loadcarrier
2- Articulated vehicle
3- The heavy tractor vehicle.

1- The single-unit vehicle :-

These are of conventional four wheel type and are of two axle design. These vehicle the front axle is a steering non-driving axle and the rear axle is the driving axle.

2- Articulated Vehicle :-

A lower powered three wheeler with a single steering wheel in front and a conventional rear driving axle is an example of articulated vehicle.

3- The heavy tractor :-

Heavy tractor or independent tractor are generally move heavy load they commonly operate in pair either in tandem or as pulter and push car

Types of Automobile ? → with respect to different purpose these are classified

1- With respect to the use :-
   (a) Autocycle
   (b) Scooty
   (c) Car
   (d) lorries
   (e) tractor

2- With respect to capacity :-
   (a) HTV (heavy transport vehicle) bus, truck
   (b) L TV (Light transport vehicle) Car, Jeep
   (c) TV (Medium transport vehicle) Tempo, mini

3- With respect to fuel used :>
- (a) Petrol
- (b) Diesel
- (c) Gas
- (d) Electric
- (e) steam

4- With respect to make :-

5- With respect to wheels and axles :-
- (a) Two wheelers
- (b) Three wheelers
- (c) four wheeler
- (d) 6 axle

6- With respect to the drive :-
- (a) left hand / right hand drive
- (b) Fluid drive
- (c) Front wheel / rear wheel drive
- (d) single wheel / Two wheel / four wheel / six wheel

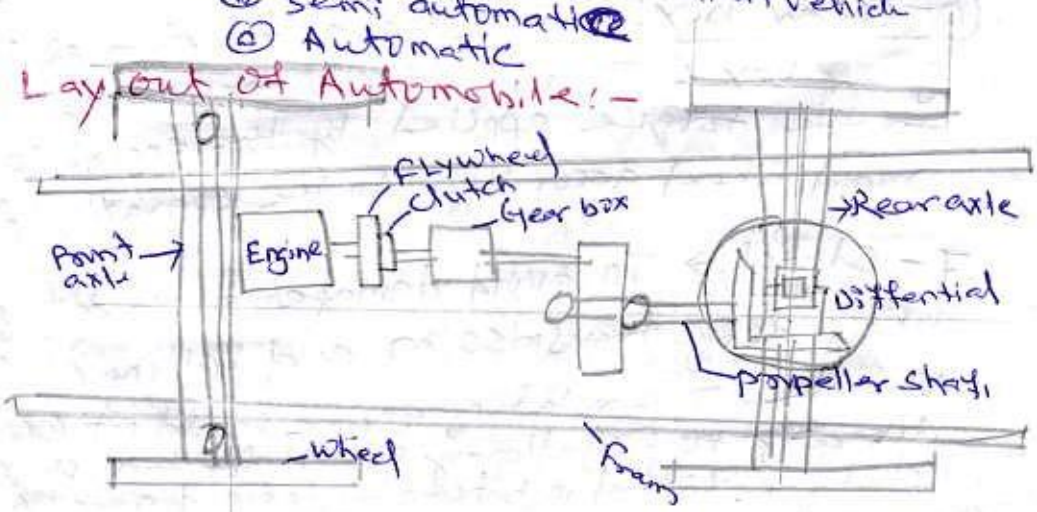
7- With respect to the motion :-
- (a) reciprocating - piston engines
- (b) rotary - Gas turbine

8- With respect to the suspension
- (a) conventional - leaf spring
- (b) Independent - Coil, torsion bar, pneumatic

9- With respect to the body and number of Doors :
- (a) sedan - two / four door
- (b) convertible - Jeep
- (c) station wagon
- (d) Delivery van

10- With respect to transmission :-
- (a) conventional - Indian Vehicle
- (b) semi automatic
- (c) Automatic

Layout of Automobile :-



1-Wheel :- The wheels are fitted below the car chessis to support the load of the vehicle and passanger as well as run the car. They are fitted with hollow rubber tubes filled with air under sufficient pressure. The shocks caused by road irregulaities are absorbed by them.

2-Front axle:- It is used for steering front wh carried on stub axles swivelling upon kingpins at extrimitees.

3-Rear axle:⇒ For fixing rear wheel a tube sh shaft enclosing driving shaft with suitable bea for rotating the wheel in used.

3-propeller shaft:⇒ It is a universal jointed shaf its function is to transmit the power from the rear ~~end~~ of the gear box to the final reduction gear in the rear axle.

4.-Frame: For attaching and supporting the various components of the vehicle. the assembl vehicle without body called chassis.

5-Diffential :⇒ The differential gear carry the power from propeller shaft to the rear wheel axle it helps the two rear wheels to turn at different speed when ~~steering~~ rounding in curve. The differential ensure that the final output torque is equally distributed between the two wheel without any consideration of their relative spee

⑥-Gear box:⇒ The main function of the gear box is to provide the necessary variation to the torque applied by the engine to the road wheel according to the operating condition

7-Clutch:⇒ To avoid damage to the driving wheel duny transmission and jolting of the vehicle. The rotating engine should not connected directly to a stationary shaft. for this purpose clutch is fitted in between engine and gear box

1.2 CLutch

Clutch is a mechanism which enables the rot motion of one shaft to be transmitted when des to a second shaft which is coincident with that of first.

Requirement of clutch:-

1- Torque transmission:→ The clutch should be a to transmit the maximum torque of the engine un all condition. It design to transmit 125% to 150% of the maximum engine torque.

2- Gradual engagement:- The clutch should posit take the drive gradually without the occurance sudden jerks.

3. Heat dissipation:→ During clutch application large amount of heat are generated. The rubbing surface should have sufficient area and mass absorb the heat.

4. Dynamic balancing:→ This is necessary partic in the high speed clutches.

5. Vibration damping:→ suitable mechanism sh be incorporated within the clutch to eliminate noise produced during transmission.

(6) Size:→ The size of the clutch must be sm possible so that it should occupy minimum spac

7. Inertia:→ The clutch rotating parts shou have minimum inertia. otherwise when the clu is released for gear chaying, the plate will keep on spining, causing hard shifting and g clashing inspite of synchronize.

8- clutch free pedal play:→ To reduce effe clamping load on the carbon thrust bearing and wear there of sufficient clutch free pedal play must be provid

9- Ease operation:→ For hegher torque transmis the operation of disengaging the clutch must not be e tiresome of the driver

1- Friction clutches
2- Fluid fly wheel

* The friction clutches works on the fact that friction is caused when two rotating disc comes in contact with each other.

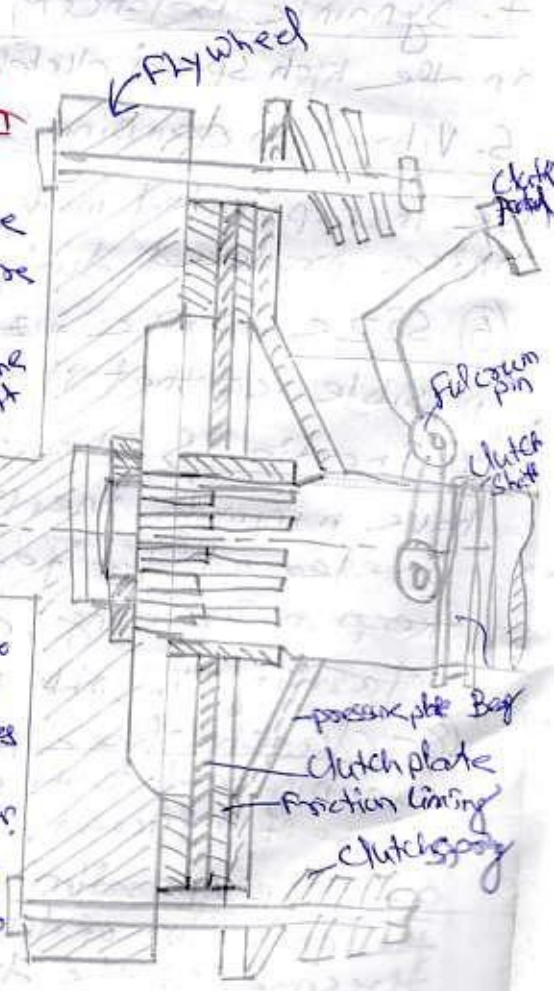
But the fluid fly wheel works on the transfer of energy from one rotor to the other by means of some fluid.

* Friction clutches may be dry or wet type Dry type is majority in vehicle mainly lower the co-efficient of friction. Wet type is used in modern vehicle.

Dry friction clutches :->

1- Cone clutch
2- Single plate
3- Multi plate
4- Semi centrifugal
5- Centrifugal

Single plate clutch



Friction plate is held between the fly wheel and pressure plate. There are springs depend upon design arranged circumferentially which provide axial force to keep the clutch in engaged position. The friction plate is mounted on the hubs which is splined from inside and thus free to slide over the gear box shaft. Friction facing is attached to the friction plate on both sides to provide two annular friction surface for transmission of power. A pedal is provided to pull the pressure plate against the spring force whenever it is required to be disengaged

When the clutch pedal is pressed, the pressure pl
moved to right against the force of the spring. Th
is suitable linkage and a thrust bearing. With th
movement of pressure plate, the friction plate
released and the clutch is disengaged.

Advantages

* With the single plate clutch, gear changing is easier than with the cone clutch. because the pedal movement is less.
* It does not suffer from cone clutch. Binding of cone etc and hence it is more reliable.

Disadvantges :→

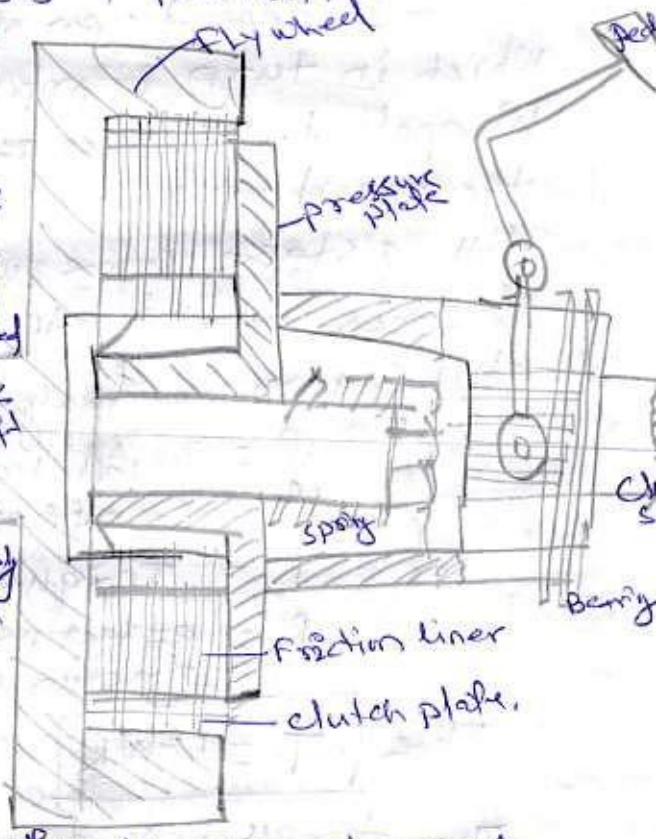
* As compared to cone clutch, the spring have to be more stiff and this means greate force required to applied by the driver while disengg
* when cover is bolted on to the fly wh pressure plate is further pushed back against the sp causing them to be compressed further.
* noise due to release lever when the clutch is in engaged position.

Multiplate clutch

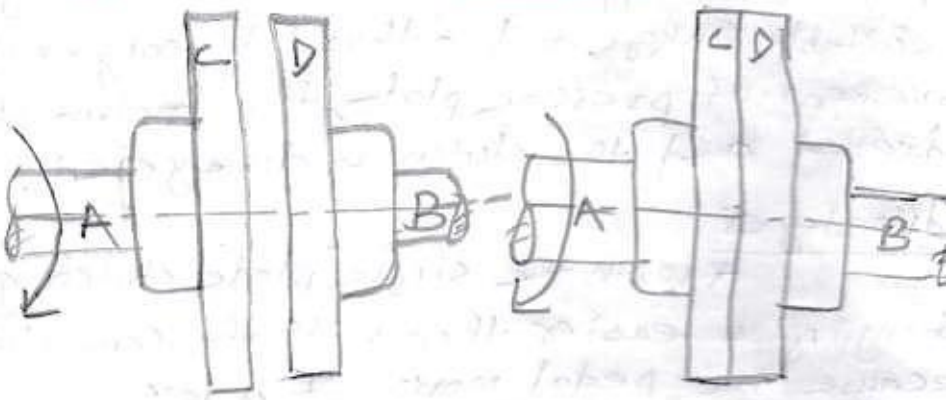
The multiplate clutch is an extension of single plate type where the number of friction and the metal plate increased

The increase in the number of friction surfaces obviously increase capacity of the clutch to transmite torque. the size remaining fixed. the overall diameter of the clutch is reduced for the same torque transmiss as a single plate clutch.

This is used in heavy transport vehicle and racing



Working principle of clutch



Let shaft A and disc C be revolving at same speed say N rpm.

Shaft B and disc D keyed to it are stati initially when the clutch is not engaged.

Now applied some axial force W to the disc so that it comes in contact with disc C. As s as the contact is made the force of the fri between C & D will come into play and cons the disc D will also start revolving. The sp of the D depend upon friction force prese which in turn is proportional to the force W applied. If W is increased gradually the speed of D will be increased correspo till a stage come when the speed becomes equal to the speed of C the clutch is said is fully engaged.

Let W = axial load applied
μ = Co efficient of friction
T = Torque transmitted
R = effective mean radius of friction surface

Then $\boxed{T = \mu W R}$

Thus torque T is depend upon three factor μ W and R

1.3 Gear Box

Torque is increased in the engine at the co of its speed, the gear box is used as the me of changing the ratio of power application changing the leverage which is having at the driving wheel.

The gear box is fitted between the clutch the rear wheel axle helps the engine to utili its power economically under varing loads condition by a suitable arrangement of rear train inside a metal casting. It alter the relationship betw engine speed and its vehicle speed for fulfi the above purpose. Depending upon the load and road condition, the road wheels get power of the engine in varing ratio.

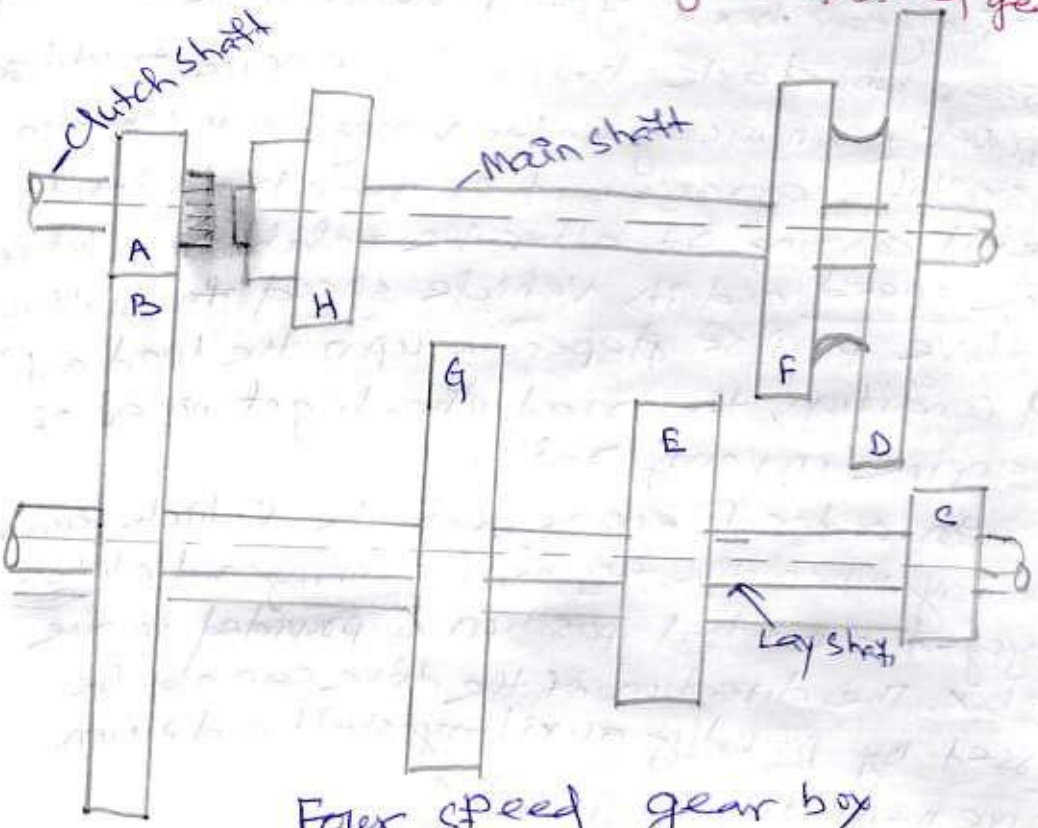
In order to ensure that the vehicle rema stationary when the engine is running and clutch is engaged a neutral position is provided in the gear box. The direction of the drive can also be reversed by providing auxiliary shaft and pinion arrange ment in the gear box.

Necessity of Gear box :-

An IC Engine produces little power at low rpm and maximum power at the given speed depending on the eng with direct coupling, a set of fixed road speed provided to the engine by this. but this would onl suitable on level ground because when climbing, vehicle has to be lifted as well as propelled on slight gradient. The accelerator could help to ove come this on level ground but on steep gradien even at full throttle the engine speed would rapidly decrease and finaly stop, In order to maintain engine speed on all condition of load and speed of the engine up while sacrificing some road speed. In order to enable the engine to run fas in relation to the road wheel as well as multiplying t torque, a gear box is used.

In order to understand the necessity of a gear box, the resistance acting to the motion of the vehicle must be considered. The tractive effort of vehicle available at speed should also be considered.

Construction and working of 4 speed gear b



Four speed gear box

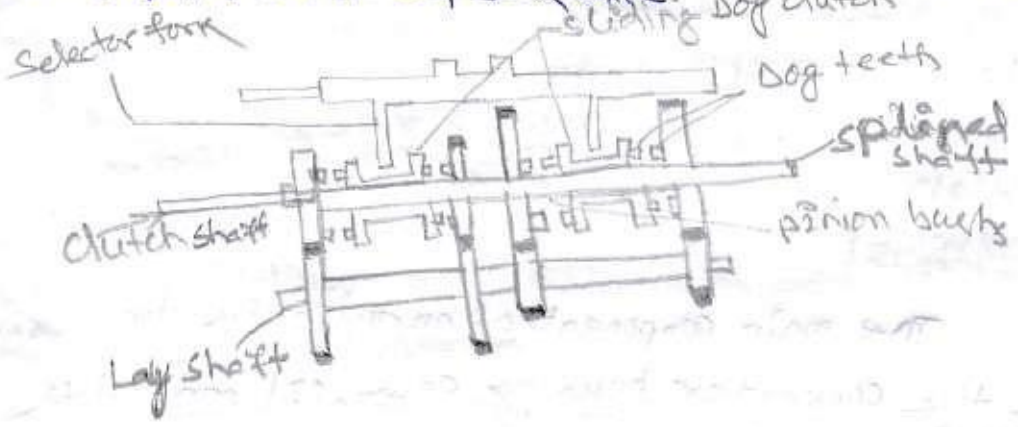
For obtaining better performance four speed gear box is used. mainly at lower powered cars necessarily used. many time it has been se that in driving a car it fails to climb a hill on top gear while on a slightly lower gear it would climb easily. Under these conditions a car is forced to surmount the hill at a slow speed with the three speed gear box becaus the second gear ratio provides gear reducti Now the car is forced to climb more rapidly b the third gear ratio of four speed gear since it is invariable higher than the second gear ratio of a three speed gear box. moreover the second speed ratio of four speed gear box is usually arranged with a lower rati than that of the three speed one.

Hence it is possible to start the vehicle from rest in second gear except on ~~climbing~~ inclines or with fully loaded vehicle in which case only first gear is only used for starting.

A commercial pattern fours speed gear box has gear slid along the splined primary shaft to engage with their mating members. The engine drive to the smaller gear which is in constant mesh with large layshaft gear is taken through the clutch unit. Therefore the revolving speed of the layshaft is lower than that of the engine crankshaft. The ratio of the two speed is the same as the ratio of the number of teeth or smaller gear to those or the largergear.

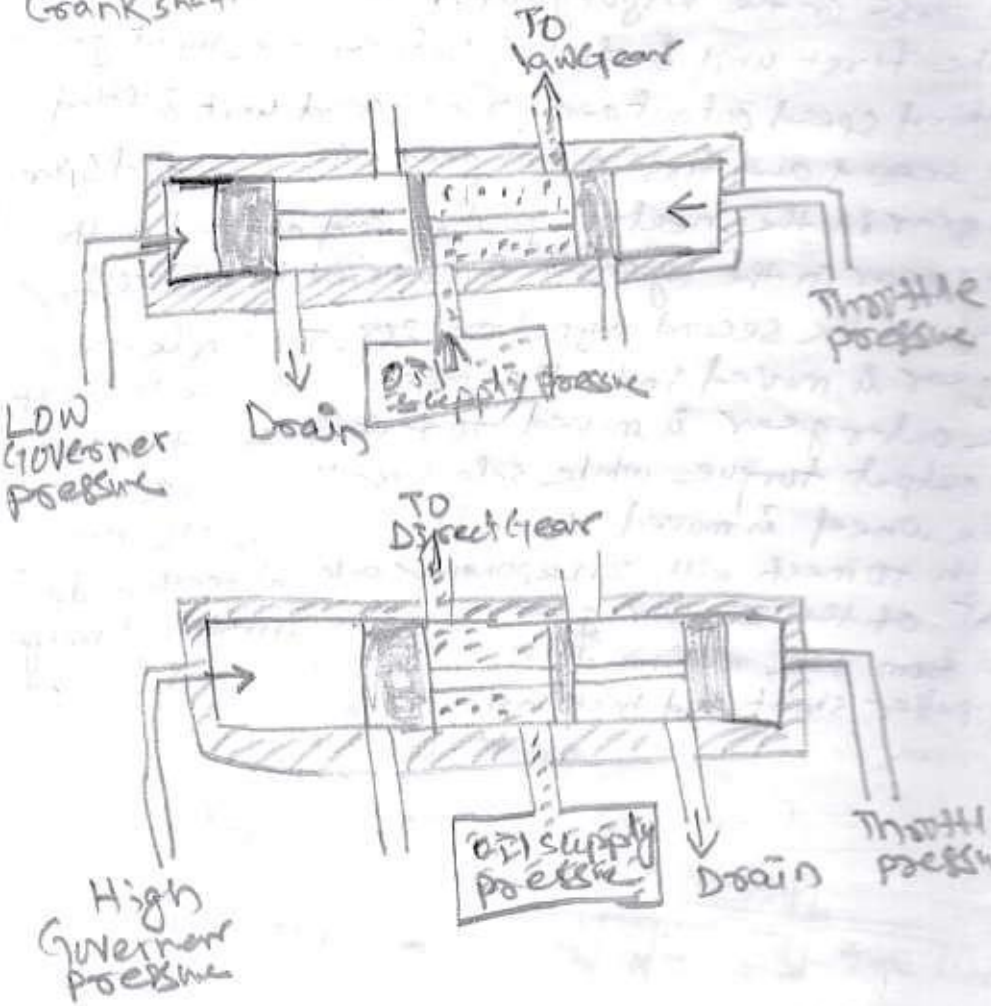
The first unit is fitted between the input gear and the third speed output ger. The second unit is fitted between second and first output gear. An integral spur toothed gear in the neutral position and aligned with the spur gear on the layshaft is carried by the sliding outer hub of the second synchronizers. The single-spur idler gear is moved into the mesh with the lay shaft and the outer gear is moved to reverse the direction of the output torque while selecting the reverse.

The wheel is moved to left to cause its internal cut teeth to mesh with corresponding external teeth made the right of the smaller gear. Now the drive is directly taken from the engine to the main shaft and finally to the propellar shaft and back axle.



1.1 Automatic transmission

F = Free wheel
BR, BF & BS - Brake



The main components of an automatic transmission are the converter housing, case, oil pan and the extension housing. The converter housing encloses the torque converter and may be integral with the case or separately bolted to the case. The case contains the epicyclic gear train while the extension

housing encloses the output shaft. The oil pan
bolted to the case. The entire transmission unit
attached to the engine block by means of bolts thro
holes in the converter housing flange.

The case is usually made of aluminium while the
oil pan is ordinarily made of stamped steel or alumin
The oil pan contains the transmission fluid.

The first fig shows the automatic transmission s
is observed that it is simply a combination of the
torque converter and epicyclic gear train.

The turbine of the torque converter drives the ri
gear of the first gear train through the free wheel
The drive to the ring gear of the second gear train
is then taken from the planet carrier of the firs
train so that the two act in series.

This arrangement gives the three forward and on
reverse speed. For direct gear clutch A is engaged, the
second gear is obtained by engaging clutch B and applyi
brake BS. The application of both brakes BS and BF
gives the first i.e. the lower most gear. For reverse
gear BR brake is applied.

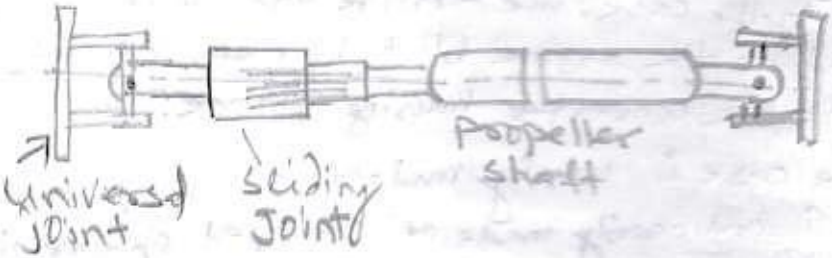
The selection of particular gear and applic
of corresponding clutch and brake is done by hydraulic
The hydraulic pressure is regulated by two factor
(1) Car speed that control oil pressure on one side of the
shaft valve
(2) The throttle opening controlled by the driver throu
accelator pedal.

which control the oil pressure on the other side o
the shaft valve.

At low speed, the governor pressure is less d
to the centrifugal force. The throttle pressure is the
more than governor pressure which cause the shift
valve to move left. This connect the oil under pressu
to go to the brake drum for applying low gear.

Similarly at high speed, increase governor pressure
moves the shift valve toward right, connecting oil pr
applied to the ~~supplying~~ to system engage direct gear

1.5 Propeller Shaft



Propeller Shaft is the shaft which transmits the drive from transmission to the bevel pinion or worm of final drive in front engine, rear drive vehicle. It is also called drive shaft.

It consists of mainly three parts ① shaft ② one or two universal joint ③ slip joint.

① Shaft :- This has to withstand mainly torsional load. It is usually made of tubular cross section. It also has to be well balanced to avoid whirling at high speed.

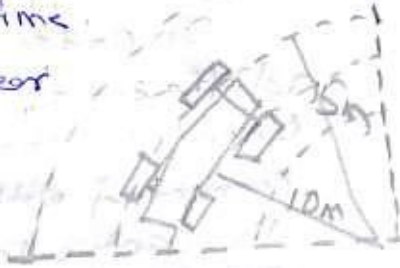
② Universal joints :- One or two universal joints depending upon the type of rear axle drive used. The universal joint account for the up and down movement of the rear axle when vehicle is running.

③ Slip joint :- Depending upon the type of drive, the slip joint may be there in shaft. This serves to adjust the length of the propeller shaft when demanded by the rear axle movement.

In some design, slip arrangement is slightly different. In these the universal joint and splined slip yoke are located at the transmission end of the shaft where these are held in alignment by a bushing in the transmission rear extension. This splin is lubricated internally by transmission lubricant or grease. Sometimes rubber element is incorporated in between the two sliding tube to make the relative movement smooth and noiseless

1.6 Differential

Differential:- When a car is taking a turn, the outer wheel will have to travel greater distance as compared to the inner wheel in the same time.



Therefore the car has a solid rear axle only and no other device.

There will be tendency for the wheel to skid. Hence if the wheel skidding is to be avoided, some mechanism must be incorporated in the rear axle, which should reduce the speed of the inner wheel and increase the speed of outer wheel when taking turns. It should at the same time keep the speed of all the wheel same when going straight ahead. Such device which serve above function is called a differential.

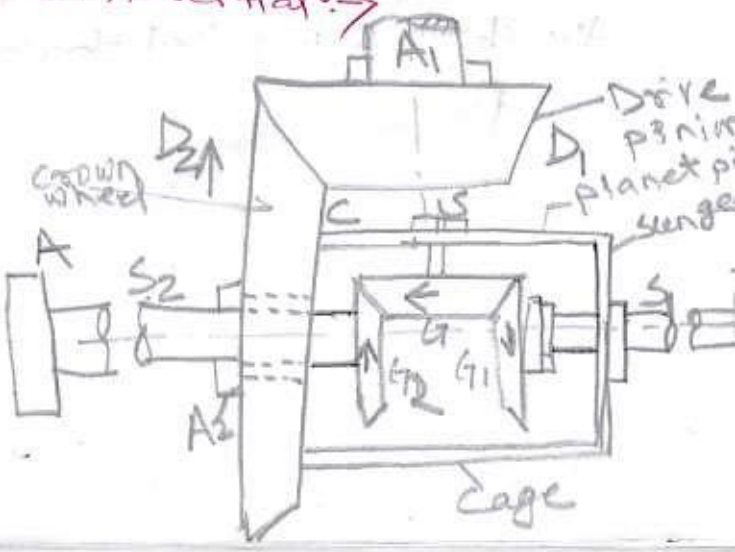
Types of differential:-

1. Bevel gear differential
2. Limited slip differential.
3. locking differential
4. cone clutch differential

(*) Bevel gear differential has the differential pinion mounted on short axle or stud carried by a differential case or frame.

(**) Limited slip differential consists of a multi disc clutch pack fitted behind each sun wheel. The inner and outer plates are splined respectively to the sun and case wheel.

Principle of differential:->



The principle of a differential is very simple. It is similar to that of an ordinary weighing beam. For a beam remain stationary when loads are applied to its ends must be equal

In order to understand the principle of a differential, consider two discs or sun wheels linked by shaft to the wheel and inter-connected with lever. By appling a force at the centre lever each disc will received an equal share i.e. half the force applied. The resistance R opposing the motion of the shaft will effect the movement of disc. The lever would tilt and push the first disc forward a greater amount. If a larger resistance act on second disc. Replace the disc system by bevel gear called sun wheel and levers by planet gear.

Suppose two shaft S_1 & S_2 are attached to the larger bevel gear G_1 & G_2, Attached to the shaft S is a pinion G meshing with G_1 & G_2. By pulling the shaft S forward without rotating it about its axis, the pinion G will not revolve. Now pinion G meshed with gear G_1 & G_2 is acting merely as connection or clutch between them and turns them about their axes resulting the shaft S_1 & S_2 to revolve equally in the direction in which the shaft S is pulled. By keeping S_2 stationary its gear G_1 will not revolve when the shaft S is pulled forward.

NEED OF BRAKING SYSTEM:-

Braking a vehicle is reverse of acceleration a vehicle. The kinetic energy of the vehicle is dissipated as heat with the help of brake mechanism. As in case of the acceleration, almost all the vehicle kinetic energy reduced is removed by brakes and converted in to heat. Therefore the rate of heat dissipation is also very important.

The rate of kinetic energy removal i.e. heat dissipation by the brakes must be higher than its addition by the engine.

General Braking requirements: →

(a)- The braking force should be independent of all the operating conditions, i.e. wheather road is uneven & flat, dry or wet, straight or winding etc.

(b)- The pedal effort required to perform should be optimally sensible.

(c)- Brake performance should not be affected by wear of its component. The braking system should require very little maintenance and adjustment and should have a long and economic life.

(d)- During braking operation, the vehicle should not drift from left to right or noise, vibration should be generated at large scale.

(e) The response timing for brake should be as short possible.

(f) The deceleration produced should be preferably remain uniform throughout its application.

TYPES OF BRAKES

The brakes for automotive use may be classified according the following considerations:-

1- purpose
2- location
3- construction
4- Method of actuation
5- Extra braking effort.

1- purpose :- From this point of view the brakes may be classified as the service or the primary and the parking or secondary brakes. The service brakes are the main brakes used for stopping while in motion. whereas the parking brakes are meant to hold the vehicle on a slop.

2- Location :- These may be located either at the transmission or at the wheels. The wheel brakes are definitely better heat dissipation point of view on account of two reasons. Firstly the location of transmission brakes from this view point is very poor and secondly there is only one brake drum. Where as in case of wheel brakes it may have four drums. which increase the area available for heat dissipation.

As incase of transmission brake the whole of the braking torque has to be transmitted through universal joint, propeller shaft, differential and the rear axle. so the braking torque is equally divided by the differential between two wheels and no special compensation is needed

So wheel brakes are used universally

3- Construction :-
From construction point drum brake and disc brakes

4- Method of Actuation :-
a - Mechanical brakes
b - Hydraulic brakes
c - Electric brakes
d - vaccume brakes
e - air brakes

5- External braking effort :-
When the weight of the vehicle more the driver cannot apply the brake easily without fatigue his effort is supplemented with some source of energy which makes the application of brake easier. this brake is called servo brake or power assisted brakes.

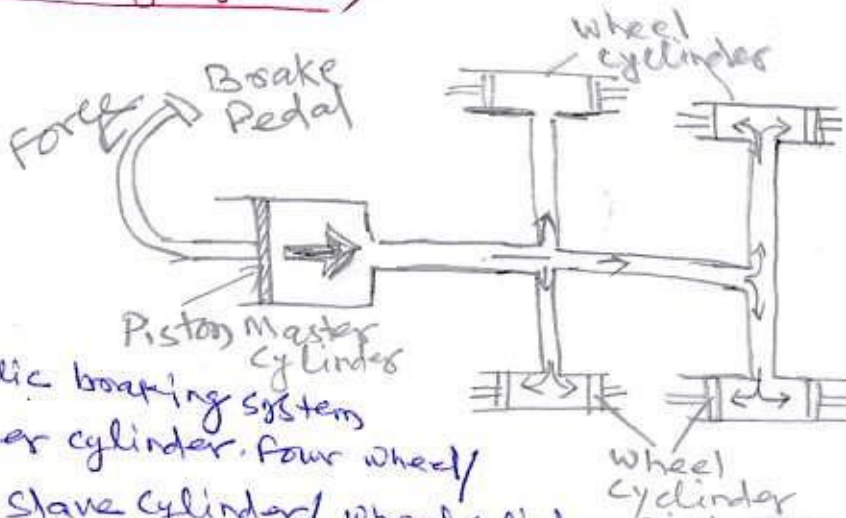
Mechanical Brakes :-

In this mechanical system of brake operation the force of driver applied to the brake pedal is transmitted mechanically through system of rod and levers to the wheel and brake shoe. The required increase increase in brake actuating force applied as pedal effort by the driver is obtained through mechanical advantage or leverage provided by levers.

The given fig shows a mechanically operated drum brake with the help of an example. The expanders is operated by means of a link rod connected to the brake pedal.

Since the pressure against drum which causes the braking action it is obvious that equal pressure and equal distance travel must be applied to all brakes for effective & ballanced braking.

Hydraulic Braking system: →



A simple hydraulic braking system consists of master cylinder, four wheel/ slave cylinders slave cylinder/ wheel cylinder and the connecting tubing and hose that branch out from the master cylinder to wheel cylinder. The whole system is a closed container filled with braking fluid.

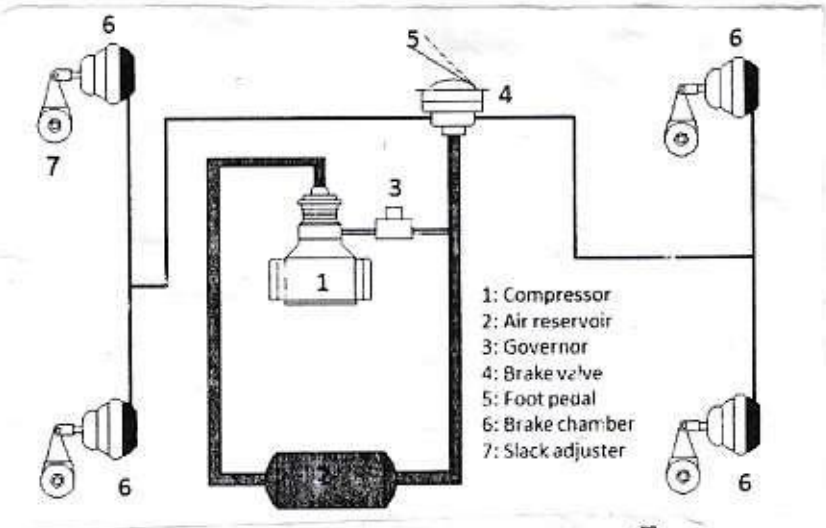
The brake fluid is incompressible and it exherts equal pressure in all direction. When the driver applies force by the brake pedal to the brake fluid in the master cylinder resulting fluid pressure is equally applied on wheel cylinders and pistons that the fluid contact.

By this contracting action the brake shoe and brake drum interlocking comes to existance and we call it braking phenomenon.

Abs Braking System :⇒

AIR-BRAKING SYSTEM

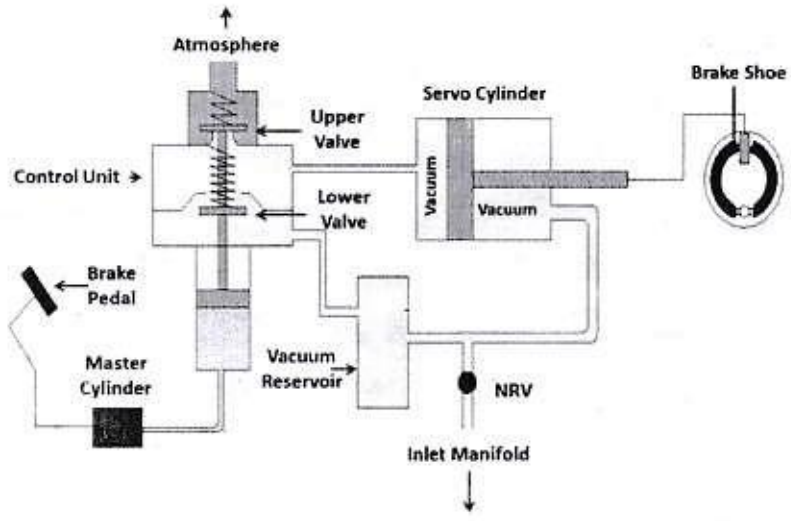
In air braking system the brake shoe operating cam is operated by means of air pressure which is developed by air compressor driven by the engine. There are separate brake chambers for the separate brake shoe operating cams. The brake chambers are connected, with the air reserv by means of pipe line. A brake valve operated by the foot pedal controls the pressure of air which affects the brake chambers. As the foot pedal is pressed down, ai acts on diaphragm of brake chamber. The diaphragm is linked with the brake shoe operating camshaft. The dia-phragm is pushed outward in, causing the brake shoe operating cam shaft for a momentum. The brake shoe expand outwards and hold the moving brake drum as they come into its contact. When press is released from the brake pedal it comes back with the help of retuen spring.



[Air braking system : Circuit]

VACUUM BRAKE

These brakes are operated with the vacuum of engine manifold. These brake include a vacuum booste to operate the cam inside a brake drum; the vacuum pump of booster operates upon the engine m vacuum and is put into action by brake pedal. The va booster consists of a cylinder inside which moves a pist which is connected to the brake shoe operating cam t the links & levers. The cylinder chamber contai to valves; atmospheric valve vacume valve which ar operated by brake pedal. As the brake pedal is pr down it closes the air or atmospheric valve & ope the vacuum valve which connects the booster cylind to the introduction manifold, when the pressure is released from the brake pedal; the moving up ped closes the vacuum valve & opens the atmospheric val the atmospheric presre acting on the piston in the cyl pushes it back resulting in the revarse movenent of cam & brake shoe.



Vacuum Booster/Brake When Brake is Released

[Vacuum braking System: Circuit]

AIR-ASSISTED H/BRAULIC BRAKE

As the name suggests the braking system is for by the hybridization of Air braking & hydraulic braki system. This system includes an air cylinder & & an hydraulic cylinder as tandem with the piston of air cylinder having largerer diameterc.

By the paschal's law, $P = \frac{F}{A} \Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \cdots$

This difference in diameter helps creating a much larger hydraulic pressure than compared to the air pressure in air cylinder.

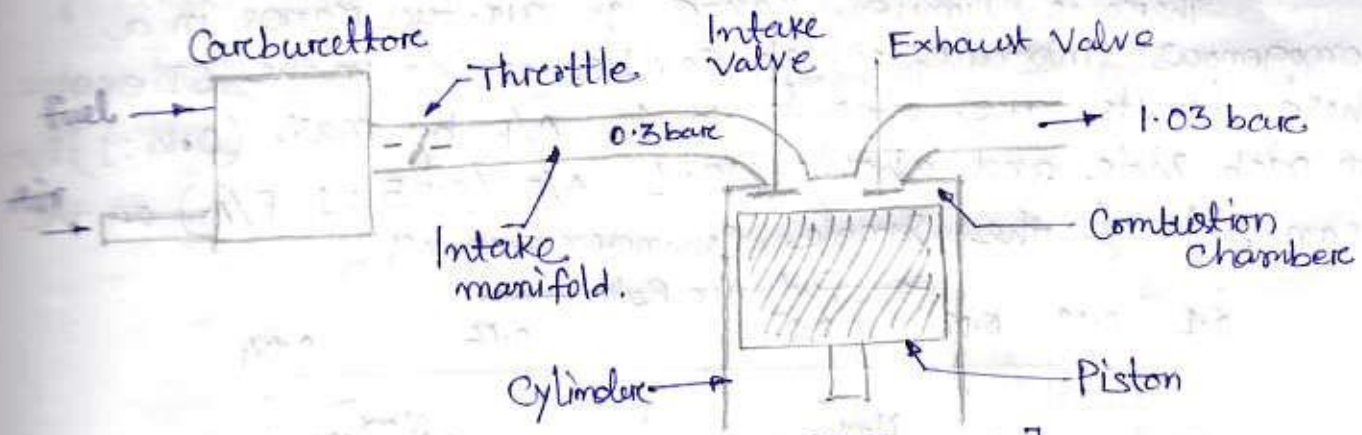
In case of hard braking; when the pedal is experienced a heavy force, the effective force in action inside the air chamber increases and ag the hydraulic master cylinder in turn experices a higherforce causing more valve movement result in a strong braking action.

CARBURETION

In the SI engine a combustible fuel-air mixture i prepared outside the engine cylinder. The process of prepar this mixture is called carburetion.

The device which acomplishes this process is called Carburettor. It atomises the fuel and mixes it with air

The overall process is achieved by induction syste of which Carburettor is a basic part. The pipe that carries the prepared air-fuel mixture to the engine cylinder is called intake manifold.



[INDUCTION SYSTEM SI ENGINE]

During the suction stroke vacuum is created in cylinder which causes the air to flow through the carburet and the fuel to be sprayed from the fuel jets. Becau of the volatility of fuels most of the fuel vaporizes a forms a combustible mixture (ful-air mixture). Howeve some of the larger dsoplets may reach the cylinder i the liquid form & must be vaporized & mixed with air during the compression stroke before ignition by the ele spark.

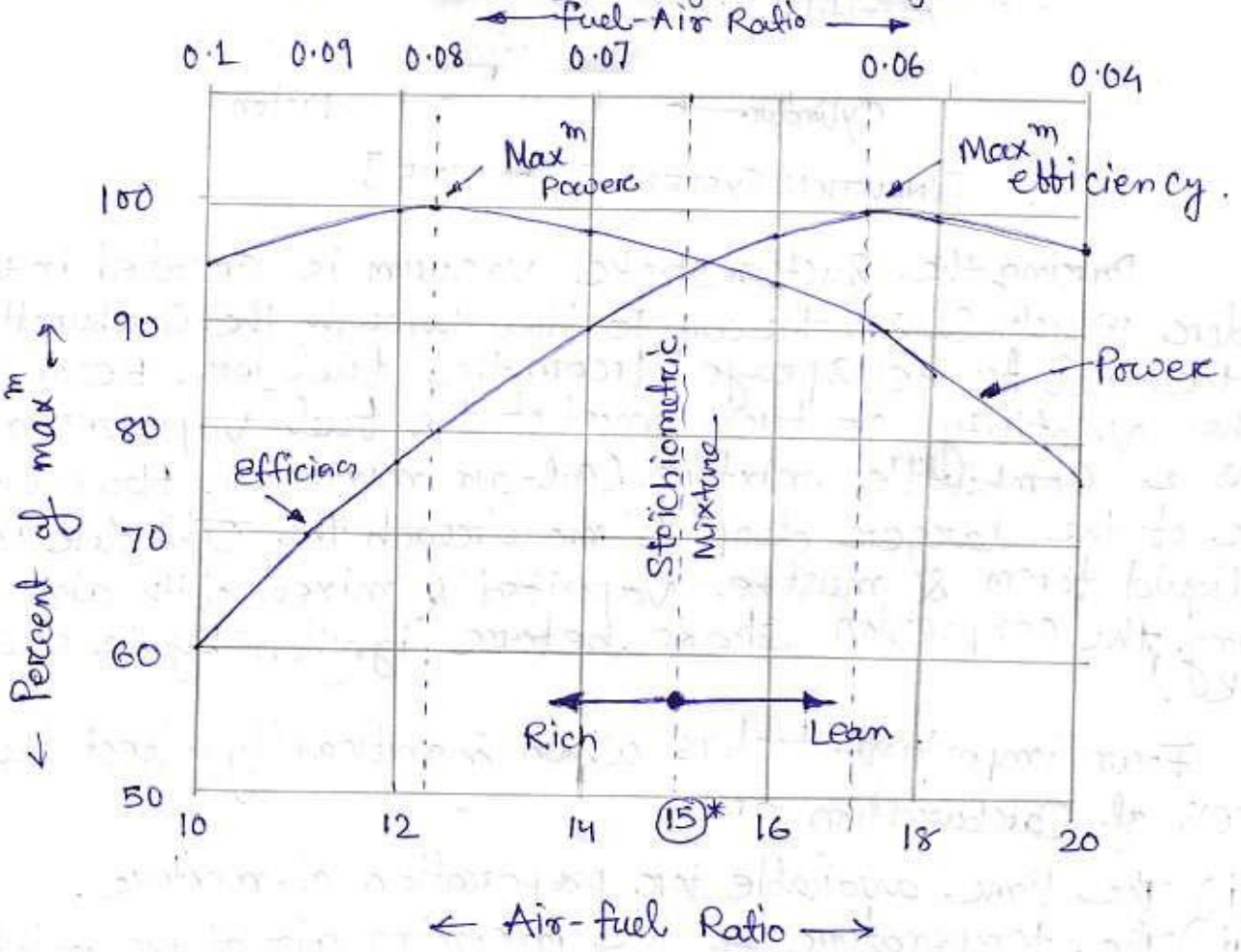
Four important factors which significantly affect th process of carburettion are,

(i) The time available for preparation of mixture.
(ii) The temperature of the incoming air of the inta manifold.
(iii) The quality of the fuel supplied.
(iv) The design of the induction system & combustion chamber.

The design of carburation in SI engine is complicated because the optimum air-fuel ratio required by it varies widely over its operational range, particularly in case of automobile engines. When the engine is idling, a richer mixture is required due to dilution of mixture by products of combustion. Again at full load condition a richer mixture is required for maximum power

AIR - FUEL RATIO

There is limited range of air-fuel ratios in a homogenous mixture which can be ignited in the SI engine. These limits are about 7:1 A/F by mass (0.14:1) F/A on rich side and about 20:1 A/F (0.05:1 F/A) on the lean side of the single cylinder engines

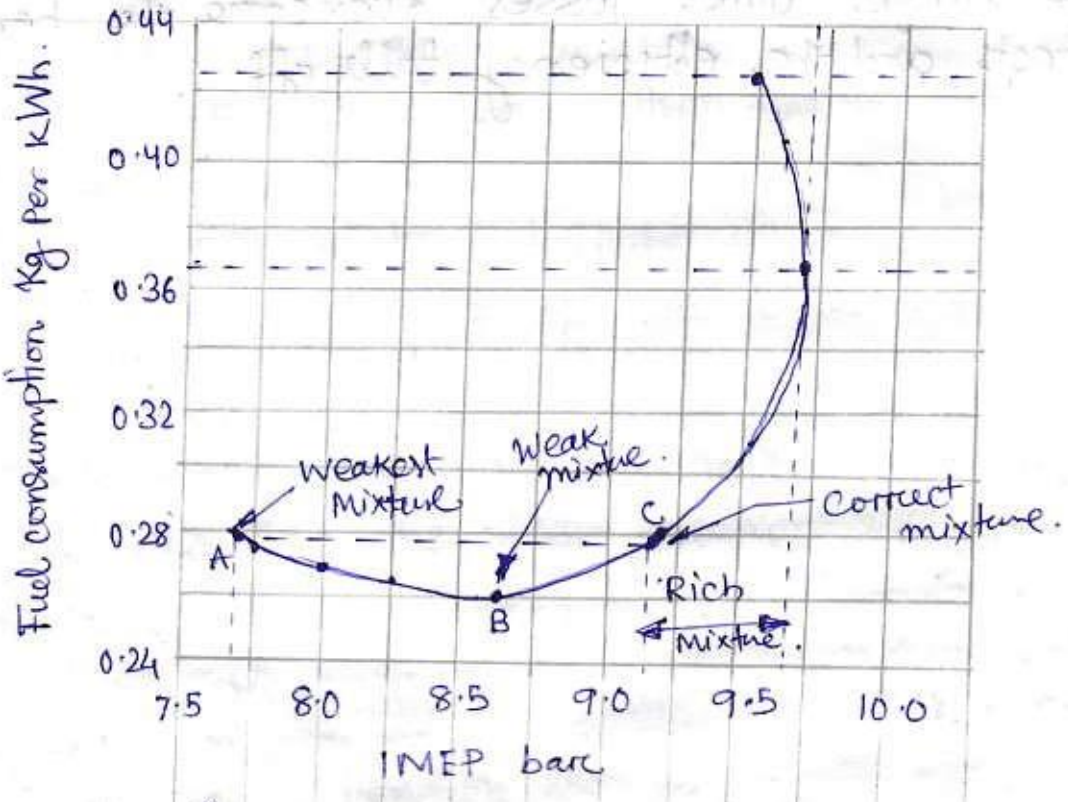


(c) Mixture Requirements for Max^{m} Power

The graph of previous page shows that the maximum power is obtained at about 12:5 : 1 Air-fuel ratio & 0·08 : 1 fuel-air ratio.

Maximum energy is released when slightly excess fuel is introduced so that all the oxygen present in the cylinder is utilized. More fuel than this doesn't help. Infact it is disadvantageous because the combustion at a large excess of fuel with the same amount of oxygen results in smaller energy released due to Partial Combustion and more Carbon monoxide is formed.

Mechanical efficiency is maximum at maximum power position.



(Fuel consumption & imep curve for Various air-fuel ratios)

(b) Mixture Requirement for minimum Specific fuel consumption

At full throttle condition maximum efficiency occures at an air-fuel ratio of 17:1.

Maximum efficiency occures at a point slightly leaner than the chemically correct A/F ratio because excess air required complete combustion of fuel when mixing is not perfect; and the power maximum temperatures associated with the inlet of the gases. However if the mixture is made too lean, the flame speed is reduced so much that the large time losses overcome the beneficial effects and the efficiency falls off.

IGNITION

Ignition is merely a prerequisite of combustion and is considered from the standpoint of the begining of the combustion process that it initiates.

The ignition process is considered as the initiation of burning in a small spherical volume called minimal volume.

The basic requirement of the spark ignition system;

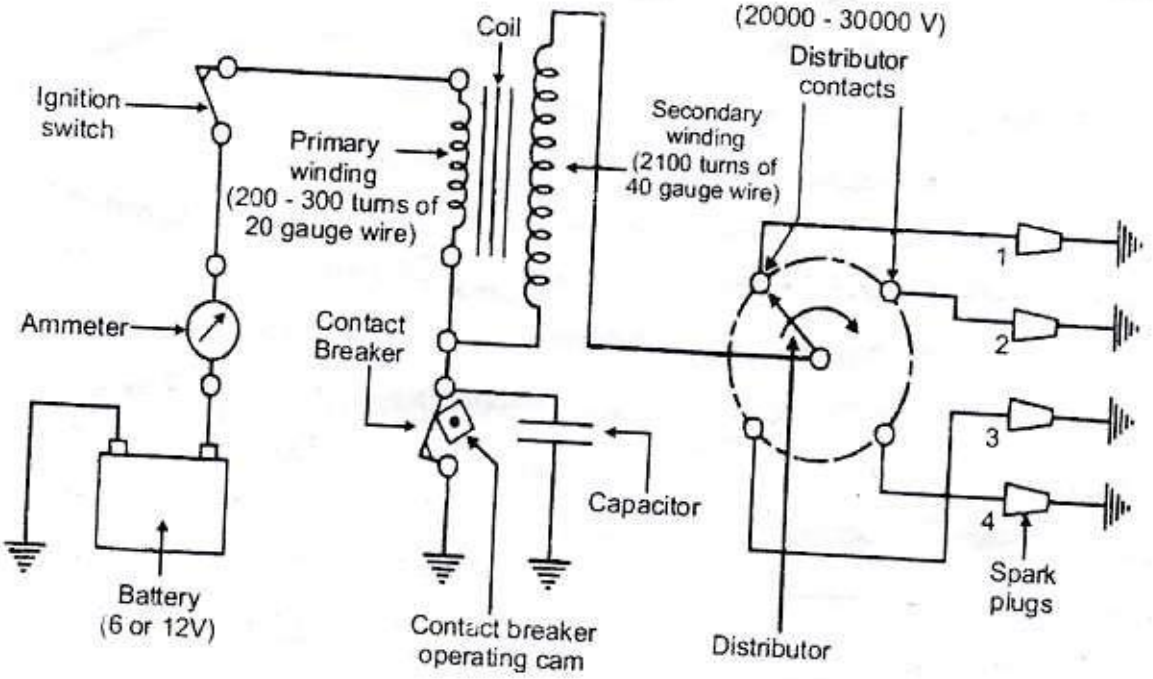
1. The system must have a source of electrical energy.
2. The system must supply sufficient current to create high energy of spark to ignite the mixture.
3. The system must produce a peak voltage greater by safe margin than spark plug breakdown voltage at all speeds even when the source of electrical energy is at its lowest voltage.
4. The duration of spark must be long enough with sufficient energy so that ignition has max^m chance of occuring.
5. The system must distribute this high voltage to each of the spark plug at exact time in every cycle i.e. it must have a distributing device.

Depending upon the sources available for generating the electricity for ignition the basic ignition system in use are
1) Battery Ignition System
2) Magneto Ignition System
3) Electronic Ignition System

Battery & Magneto Ignition System differ only in the source of electrical energy. Battery ignition System uses a battery while magneto ignition system uses a magneto to supply low voltage.

BATTERY IGNITION SYSTEM

The essential elements of a coil ignition system are shown in figure. They are battery, ignition switch ignition coil with a ballast resistor, distributor housing, the breaker points, cam, condenser, rotor a the advance mechanism, spark plug & low & high tension wiring



[Battery Ignition System Circuit]

The ignition coil consists of two coils one primary & other secondary. The primary winding is connected to the battery through an ignition switch & contact breaker. The secondary winding is connected to the spark plugs through the distributor. A typical ignition coil has 100 to 200 numbers of turns in primary winding & 20000 number of turns in secondary winding.

The primary coil, battery & the ignition switch and the contact breakers forem the primary circuit & the secondary winding, spark plug and distributor forem the secondary circuit.

Primary Circuit	Secondary Circuit
Ignition Scoitch	Secondary winding in ignition coil
Resistance unit in Ignition Coil	Coil to distributor high voltage Cable
Primary winding in Ignition Coil	Distributore reotore
Distributor Contact point Capacitor	Distributore Cap
Low voltage Wireing	Ignition Cables
	Spark plugs

A ballast reesistore is provided in sereies with the primary coinding to regulate primary Cureerent. For starting pureepose this reesistare by passed sothat more Cureerent Can flow in the primary Circuit.

A Cam rotating at Camshaft speed operates the Contact breakerpoints to open & close. When the ignition Scoitch is on & the Contact breaker points are closed, Cureerent flows from this battery through the primary coinding & builds up a magnetic field.

When the Cureerent floco in the primary coinding is stopped by opening the Contact breaker points, the magnetic field collapses, cuts across the secondary coinding and induces avdtage cohich is acomplished by a cureerent. This magnetic field howevere also cuts the primary coinding and induces a voltage in this ascoellas in the secondary coinding. The voltage in the primary coinding always opposes the action producing it & the effect is to Slowdoon the build up of the Cureerent in the primary coinding coherer breaker points closed. This prolongs curdent floco after the points open. The Slowrise in Cureerent means a s building up of magnetic field & Consequently a lower voltage in the secondary circuit. The continued flow of Cureerent after the breaker point open, reesult in a slow collapse of magnetic field & will also cause the spar to take place across the Contact breaker points beca the Cureerent treies to flow across the points as they

spark. This arcing of points increases wear & the life of the contact points is appreciably reduced. most of the energy stored in the magnetic field consumed in spark across the contact points instead across the spark plugs. & there would be insufficient energy to produce the necessary high voltage surge in secondary circuit.

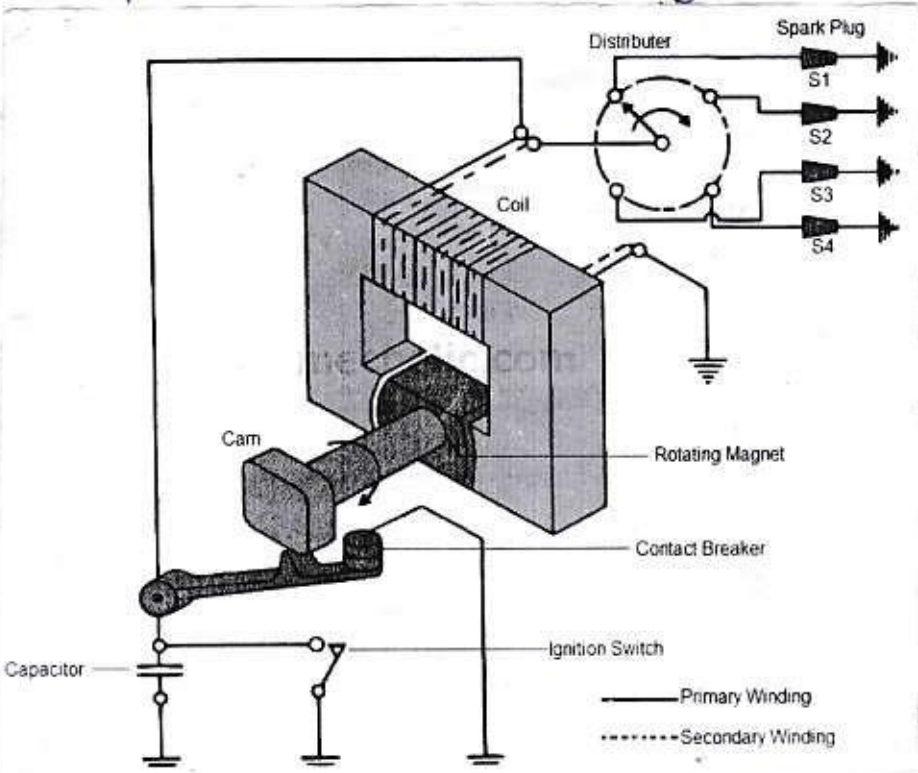
In order to obtain the highest voltage in secondary circuit, a quick collapse of magnetic field is essential. It is also necessary to prevent the arcing & consequent burning of contact points. These are achieved by providing a condenser across the contact breaker. When the contact point opens, the current instead of passing across the point in form of an arc, flows into the condenser and stored by it as it becomes charged. The charge in the condenser immidiately discharges back into the primary circuit in a direction reverse to the flow of a battery current, thus assisting in a quicker collapse of magnetic field when the contact point open.

Due to rapidly collapsing magnetic field, high voltage is induced in the primary circuit and still higher voltage of the order 11 kV or 22 kV in the secondary circuit. This high voltage in the secondary circuit passes through the distributor rotor to one of the spark plugs leads and into the spark plug, and if this voltage is higher than the breakdown voltage a spark occures across the spark plug gap causing ignition of the combustible mixture in the combustion chamber

MAGNETO IGNITION SYSTEM

Magneto is a special type of electric generator. It is mounted on the engine and replaces all the components of coil ignition system except the spark plug. A magneto, which rotated by the engine, is capable of producing very high voltage and doesnot need a battery as a source of external energy.

The below figure shows a schematic diagram of a high tension magneto ignition system. The high tension magneto incorporates in itself windings to generate as well as to step up the voltage and thus doesnot require a separate coil to boost up the voltage requir to operate the spark plug



[Circuit : Magneto Ignition System]

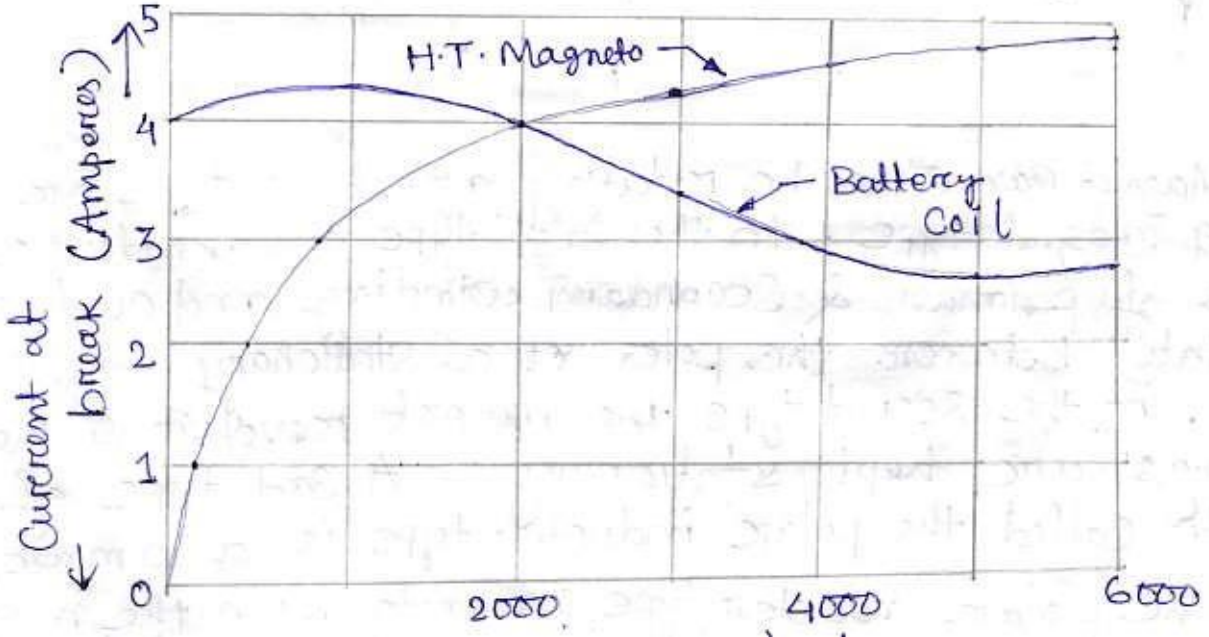
Magnet can either be rotating armeture type or rotating magneto type. In the first type the armeture consists of primary & secondary winding and condense all rotate between the poles of a stationary magneto whilst, in the second type the magnet revolves & the windings are kept stationary. A 3rd type of magneto called the polare inducter type is also in use.

In the polare inducter type magneto both the magn & the windings remain stationary but the voltage is

generated by reversing the flux field with the help of soft iron projections called inducters

The operation of magneto system is exactly same as that of the coil ignition system in that as the breaker points are opened and closed with the help of a cam. The primary circuit flux is changed and a high voltage is produced in the secondary circuit.

The below graph compares the breaker current vs speed curve of the coil ignition system with that of magneto ignition system. It can be seen that since the crank speed for starting is low the current generated by the magneto is very low. As the engine speed increases the current increases. Thus with magneto there is almost always a starting difficulty and a separate battery is needed for starting. The magneto is best at high speeds and therefore is widely used in sports & racing cars, craft engines etc. In comparison to the coil ignition system magneto system is more costly but highly reliable. However, due to poor starting characteristics & due to the fact that voltage generated is effected with the changes in spark timings, almost



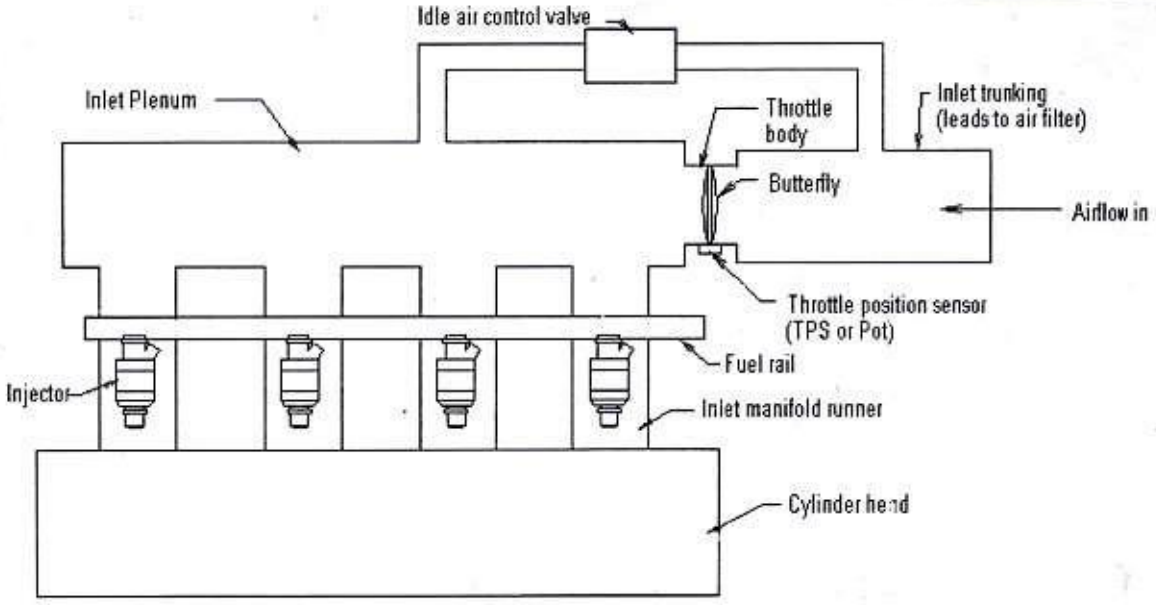
invariably the coil ignition system is preferred to the ma-neto system. The coil ignition system requires more maintainance than the magneto system. It is also heavier than the magneto system.

MULTIPOINT FUEL INJECTION (SI ENGINE

Fuel injection is a mechanism by which fuel is admitted to the engine cylinder.

In SI engines for better power output, fuel effiency, emission performance, drivability & smoothe operations fuel injection technology is implemented nowadays; though conventionally this "fuel injection" had been associated with CI engines.

Here in SI engines fuel injection takes place by atomization of fuel into the air by the action of nozzle under high pressure.

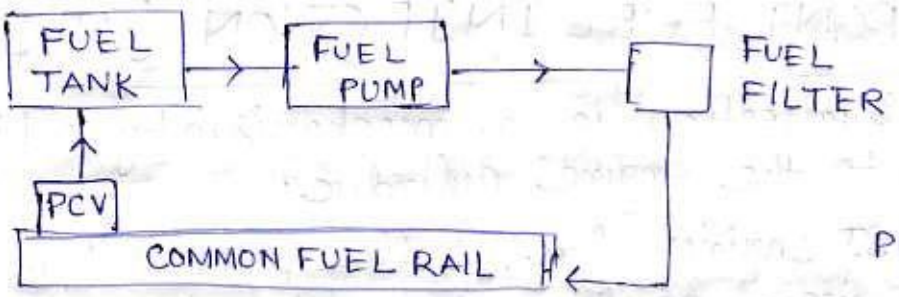


[Multipoint petrol injection SI engine]

As the figure shown above the devices are arranged to replace the conventional carebureltor for better fuel effiency, emission control.

Additionally the "fuel rail" system is comunicated with fuel tank by means of fuel filter & fuel pump

The feed back between fuel pump & fuel rail is governed by a pressure control valve connected between the fuel rail & fuel pump as shown below by block diagram.



PCV: Pressure Control Valve.

The fuel in admitted to the 'common rail' by the action of 'fuel pump' with the source 'fuel tank'. The 'fuel filter' filters the fuel with impurities, debries removed. There is a specified pressure to be maintained in common rail. If the fuel pressure goes beyond the limit; the fuel is sent back to the fuel tank by the PCV through return line.

While in operation / engine running the "throttle position sensor" senses the position of accelerator selected by the driver & induces signal to ECM (Engine Control module) Then Manifold Absolute Pressure Senser admitts the amount of air needed for complete combustion of fuel to the intake manifold.

Depending upon the firing order of the engine (most commonly 1-3-4-2) the fuel injector of corresponding cylinder starts injecting fuel from "fuel rail" and this fuel gets atomized very fast by the air inducted to the manifold runner. Continuously the air gets admitted depending upon the sequence of ignition & overall process carcries on.

FUEL INJECTION

Fuel injection is classically associated with th diesel engines.

Requirements of a Diesel Injection System

* The fuel should be introduced into the combustion chamb within precisely defined period of the cycle.
* The amount of fuel injected per cycle should be mete very accurately. The clearances between the work Part of the fuel pump as well as the size of orifice are very small.
* The rate of injection should be such that it results in desired heat release patteren
* The quantity of fuel metered should varey to meet char speed & load requirements.
* The injected fuel must be broken into very fine drop i.e. good atomization should be obtained.
* The begining & end of injection should be sharp i.e. there should not be any dribbling or after injectio
* In case of multicylinder engine, the distribution of metered fuel among various cylinders should be unifo

To accompany the objectives of precesive metering, distreibuting, timing and atomizing the following functiona elements are required in a fuel injection system.

* Pumping elements to move the fuel from fuel tank to cylinder (plus piping etc.)
* Metering elements to measure & supply the fuel accoding to the requirement of load.
* Metering Conbols to adjust the rate of the metering elements fore changes in load & speed of the engi

* Distributing elements to divide the metered fuel equally among the cylinders.
* Timing Controls to adjust the start & stop injection
* Mixing elements to atomize & distribute the fuel within the combustion chamber.

FUEL PUMP & FUEL INJECTOR

A large number of fuel pump design have been developed by various manufacturers.

BOSCH FUEL INJECTION is one of them.

The Diesel Injection System can be divided into two basic types. Air injection & solid injection.

In Air injection System the fuel is atomised & along the blast air (by compressor) it is inducted inside the combustion chamber. It is now obsolete.

In solid injection system, the injection of fuel directly into the combustion chamber without primary atomization happens. This is also called airless mechanical injection. The solid injection system has two basic elements.

(i) a pressurising unit (the pump)
(ii) an atomising unit (the injector.

FUEL PUMP

The given fuel pump is "Bosch Fuel Injection Pump". It consists of a barrel in which a plunger reciprocates when driven by a cam shaft. The plunger has a constant stroke and is single acting. Pump barrel and the plunger have between them a very small clearance, of the order of only 2 to 3 thousands of a mili-meter. Such a low clearance provides a perfect sealing without special packing even at very high pressure and low speeds. This requires that b barrel & pump should be replaced as a complete element a not one of them. The pump barrel has two radially oppo holes. These are inlet & control port.

In order to vary the quantity of fuel delivered per stroke a vertical channel, extending from top face of the plunger to an annual groove, is provided on the upper part of the plunger.

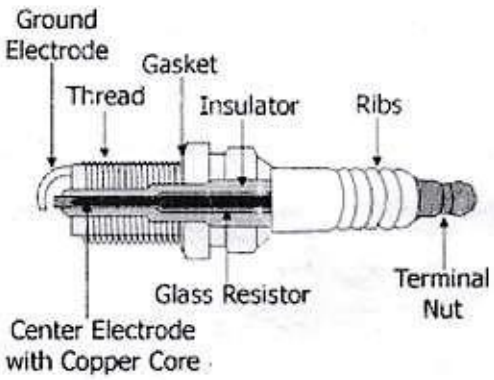
Usually the top edge of the upper end is milled in the form of a helix. The upper end is also called control edge During the delivery stroke the cam raises the plunger up & a plunger return spring brings it back to bottom dead centre position

SPARK PLUGS

The function of the spark plug is to provide a gap in the combustion chamber for the discharge of a high voltage electric pulse that will ignite the air-fuel mixt at the desired point in the cycle. To do this effectively the spark plug must satisfy number of requirements.

1. The spark plug must provide a gap spacing & to be positioned in the combustion chamber at such a locat that allows smooth engine operation over fuel opera range from idling to wide open throttle running co maximum fuel economy.

2. No part of the spark plug must ever become hot enough to cause pre-ignition (ignition of mixture before the occurance of spark). Pre ignition will occur if the surface temperature exceeds 950°C.

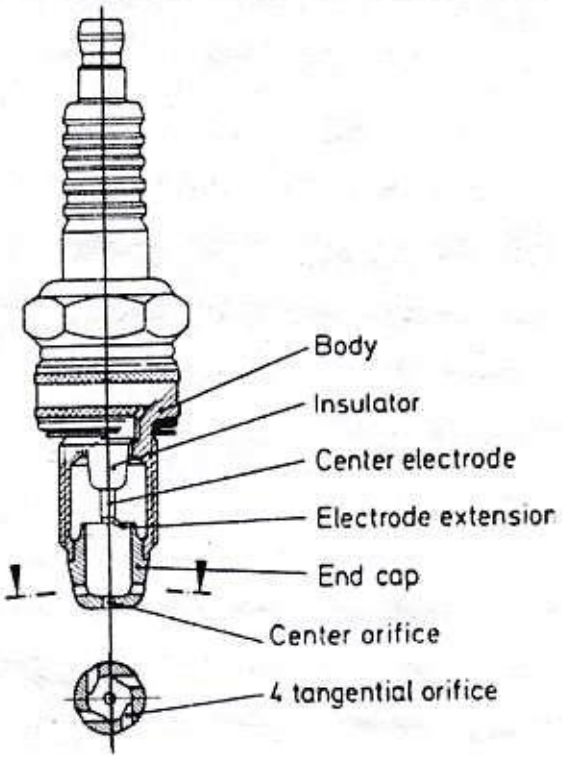


3. The modern spark-plug may have to conduct a high tension current with potential difference as much as 25 kV under occasional operating cond such as that of sudden throttle opening at lo speed after light-load running. Therefore the size, composition and temperature of electrodes should be such that erosion from electric disch between electrodes & that due to chemical action of the combustion products is minimum

4. The firing end & the spark-plug should ha adequate resistance to fouling. A tempera in excess of 400°C will burn off carbon dep while a long insulator tip and a large clea volume will minimize both carbon & lead fouling.

5. The spark plug has to coith stand widely fluctuating temperatures & pressures in the engine cylinder. The pressure can be as high as 50 bar. This requires that the insulator mater must possess desirable properties of high electrical resistance, good thermal conductivity & sufficient mechanical strength. The best material for electrode is platinum or platinum-Tungsten alloy.

The given figure shows a typical spark-plug. It consists of a centreal electrode enclosed in a Ceremic insulator. The other electrode i.e. earth electrod is attached to the under side of the metallic shell provided with a rust resistant finish on its exteriore. The lowere paret of the insulatore is fitted into the crimped upperc paret of the shell body. The lowerc paret of the shell body is provided coith threads to fit into the walls of the Combustion chambere. The insulator is made pressure-tight in the body by an internal gasket on the lower side of the sillament seals on the upper side. Plugs usually have flagged plug body. Some plugs have a tappered seating, which allows a pressure tight line constant with a similar seat in the cylinder head.



[Spark plug]
SI engine

COMMON IGNITION TROUBLES & REMEDIES

There is a certain time interval between instant of spark & instant where there is a noticable rise in pressure due to combustion. This time interval is called Ignition lag.

Auto Ignition

A mixture of fuel-air when reacts spontaneously at a certain pressure by simple chemical reaction and ignites the mixtures we call it auto ignition. This auto ignition leads to abnormal combustion which results in "detonation" or knocking in SI engines. The detonation is resulted from the vibrations set by several pressure waves generated due to ignition, auto ignition in the same combustion chamber.

In SI engines 'knocking' occures near the end of combustion where as in CI engines it happen at the beginning of combustion.

Detonation is highly undesired for smooth engine operations as it results in noise, vibration of frame, mechanical damage like erosion of piston crown, undesirable blow marks in piston.

Detonation increases the rate of heat transfer to the combustion chamber wall because of rapid combustion of fuel at multiple front in CC.

Eventually the economy of power & overall efficiency fades off.

Starting of Engine

If the engine is overcooled due to poor cooling system design or due to cold weather it is observed that the engine is not so easy to start. Even in

fuel are affected upto some remarkable extent and put problems in engine starting & running.

To sort out these problems we should always keep on mind that the engine should be sufficiently hot en to perform; therefore a proper cooling system should be designed to cope with this situation & to maintain a desirable range of temperature for the engine.

Secondly proper R&D should be carried out to m these fuels susceptible enough to maintain their phys & chemical properties in different range of temperate, hum etc.

Seizure of engine

Just like the previously discussed problem seizure engine is resulted from improper cooling & lubricatio system.

If the engine is over heated because of malfunc of cooling system, the piston expands and due to this expan in volume the friction of piston rings & cylinder walls -ases eventually staping the reciprocating motion. Sar type phenomenon is also observed if lubrication syst fails. Hence rise in friction between piston & cylin wall decreases the overall efficiency or Wnet per cycle Apart from this wear & tear is in piston ring cause improper pressue gradiant in combustion chamber

Therefore a proper cooling (sensible enough maintain a desirable temperature gradiant) and lu system could eliminate these problems; it designed.

Failure of fuel pump & fuel filter

Failure of fuelpump cause inadequate or no fue which in turn makes engine impossible to run, reduction power generatation because of improper ignition etc. incre BSFC due to excess & unnecessary flow of fuel.

Only a part of the total fuel energy supplied to the internal combustion engine is converted into useful work. The work is delivered at the crankshaft and rest of the fuel energy is rejected as follows;

(i) Heat from the engine boundary due to radiation convection, and to a small extent conduction.

(ii) Exhaust heat,

(iii) Heat rejected to coolant.

NECESSITY OF ENGINE COOLING

(a) The lubricating oil used determines the maximum engine temperature that can be used. Depending upon the type of lubricating oil used, this temperature ranges from 160°C to 200°C. Above these temperatures the lubricating oil deteriates very rapidly with temperature increase, and it might even evaporate and burn injuring piston and cylinder surfaces. Piston seizure due to overheating resulting from failure of the lubri is quite common

(b) The strength of the materials used for various engine parts usually decreases with an increase in tempera and thus establishes an upper limit for the temperatu at various points of the engine. For example, for water cooled engines the temperature of cylinder head should not exceed about 270°C while for air-cooled engines, which use light alloys, this limit is as low as 200°C.

(c) The high local temperatures in addition to decreasing the strength of the materials may result in excessive thermal stresses due to uneven expansion of various engine parts & may result in cracking.

(d) High engine temperatures may be result in very hot exhaust valve, which in turn may give rise to pre-ignition and detonation.

(e) If the cylinder head temperature is high, the volumetric efficiency and hence the power output of the engine is reduced.

Thus it is clear that some form of cooling must be provided to keep the temperature of the engine low in order to avoid the loss of volumetric efficiency and hence power, engine seizure and to avoid danger of engine failure.

DEFECTS OF ENGINE COOLING

(a) Overheating: There are temperature limits for an engine to perform. Apart from these limits there is optimum limit for a greater efficiency.

So the maximum temperature of engine is fixed for the maximum possible efficiency & optimum operating conditions.

If the temperature sensor fails in engine to detect this rise in temperature then despite the engine cooling accessories the engine keps on running at high temperate due to inadequate flow of coolant and seizeure of engine takes place

(b) Overcooling:

The engine must be kept sufficiently hot to assure smooth and efficient operation. At too low engine temperature starting may be difficult and above all the low temperature corrosion assumes such a significant magnitude that the engine life is greatly reduced.

At low temperature the sulphrous & sulphuric acid resulting from combustion of fuel (fuel always contain some sulpher) attack the cylinders barrel. The dew points of these acids vary with pressure and hence the critical temperature, at which corrosion asser significant proportions varies along the cylinder barre

To avoid condensation of acids the coolant temper should be greater than 70°C. Thus the cooling syste should not only cool but also keep the cylinder in temperature above a minimal to avoid corrosion & gi good performance to engine.

(c) Crank Case dilution:

If excessive rich mixture enters the cylinder of eng then some of the fuel gets condensed in the relativ cooler part of the cylinder & these condensates mov wash the lubricating oil from the cylinder walls, trav past the piston rings & get collected in the oil pan.

By washing the lubricating oil wear & tear increa in the cylinder wall. Apart from these, if these oil continuously persist in the engine oil, then it will chemically break down & lose its viscosity and eventually its lubricating effect. Th lack of lubrication will further cause more wear & tear.

Therefore care should be made while designing the cooling & lubrication system and while selecting engine oil a chemically stable engine oil must be preferred.

FUNCTIONS OF LUBRICATION

(a) Lubrication: The main function of the lubricating system is to keep the moving parts sliding freshly past each other and thus reduce the engine friction and wear.

(b) Cooling: To keep the surfaces cool by taking away a part of their heat through the oil passing over them. This cooling action usually takes place simultaneous to the lubricating function. However under certain condition lubrication system is used to keep certai engine parts cool which due to their typical locat dont come in direct contact with the cooling wate one typical example is the oil cooling of the piston of high specific output engines.

While performing its cooling function the lubricant is exposed to heating and agitation whi promote oxidation. This requires oil to possess good oxidation stability. The heat input to oil increases if the cooling function is extended to pist cooling.

(c) Cleaning: To keep the bearings and piston rings clean of the products of wear & tear and products of combustion, especially carbon by washing them awa and then not allowing them to agglomerate to form sludge.

(d) Sealing: The lubricating oil must form a good s between piston rings and cylinder walls. The oil should be physically capable of filling the minut leakage paths and surface irregularities of the mechanical sealing elements i.e. cylinders, pisto and piston rings. The oil as a sealant is subject to high temperatures and hence must possess adequate viscosity stability.

(e) Reduction of noise :

Lubrication reduces the noise of the engine. These functions are conflicting functions. The oil cools best when it is thin but seals best when it is thick. The oil must collect dirt to scavange and clean but to lubricate it must be clean. The engine produces not only power but a number of oil contaminants also. The oil should be able to absorb these contaminants without affecting its main functi

LUBRICATING SYSTEMS OF IC ENGINES

Various lubricating systems used for IC engines may be classified as,

(I) Mist lubrication system
(II) Wet sump lubrication system
(III) Dry sump lubrication system

MIST LUBRICATION SYSTEM

This system is used for 2 stroke cycle engi. Most of these engines are crankcharged i.e. they employ crankcase compression and thus are not suitable for crank case lubrication.

Such engines are lubricated by adding 2-3 percent lubricating oil in the fuel tank. The oil & fuel mixture is inducted through the carburetor. The gasoline is vaporized and the oil in its form of mist, goes via crankcase into the cylinder. The oil which impinges on the crank case walls lubricates the main & connecting rod bearings & the rea

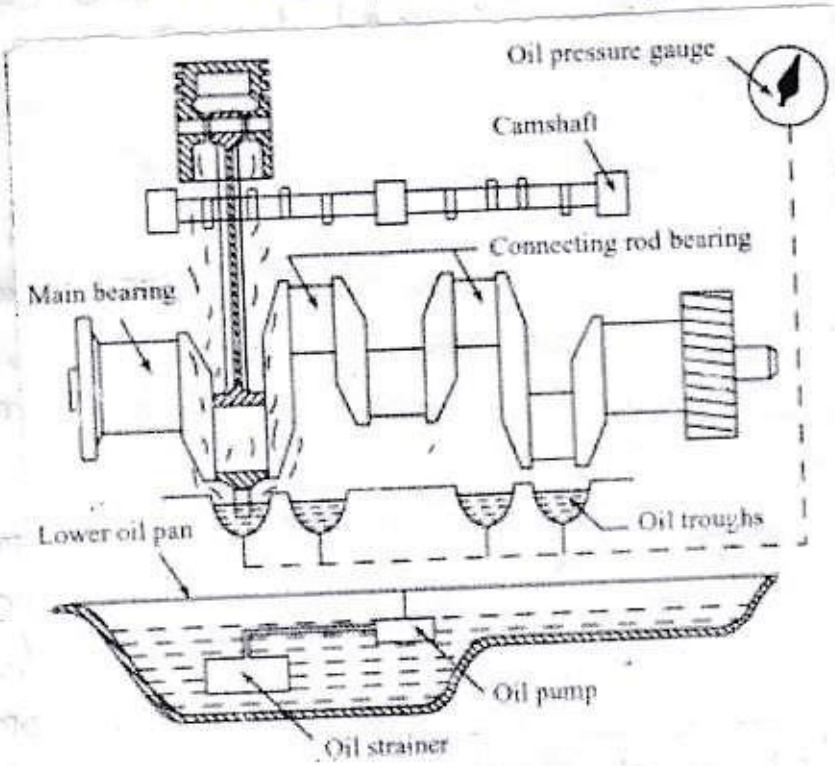
of the oil which passes on to the cylinders during charging & scavanging periods lubricates the pistons, piston rings & the cylinder.

The two stroke engine is very sensitive to particular oil & fuel combination. The composition of fuels & lubri used influence the exhaust smoke, internal corros bearing life, ring & cylinder bore wear, ring sticking, exhaust & combustion chamber deposites and one of the most irritating and difficult problem of spark plug fouling & whiskering. Therefore specially formulated ashless oils are used for 2-stoke engines.

WET-SUMP LUBRICATION SYSTEM

In wet sump lubrication system the bottom part of the crankcase, called sump contains lubricating oil from which the oil is supplied to various parts. There are three types of wet sump lubrication system,

(i) Splash system (ii) Modified splash system.
(iii) full pressure system.



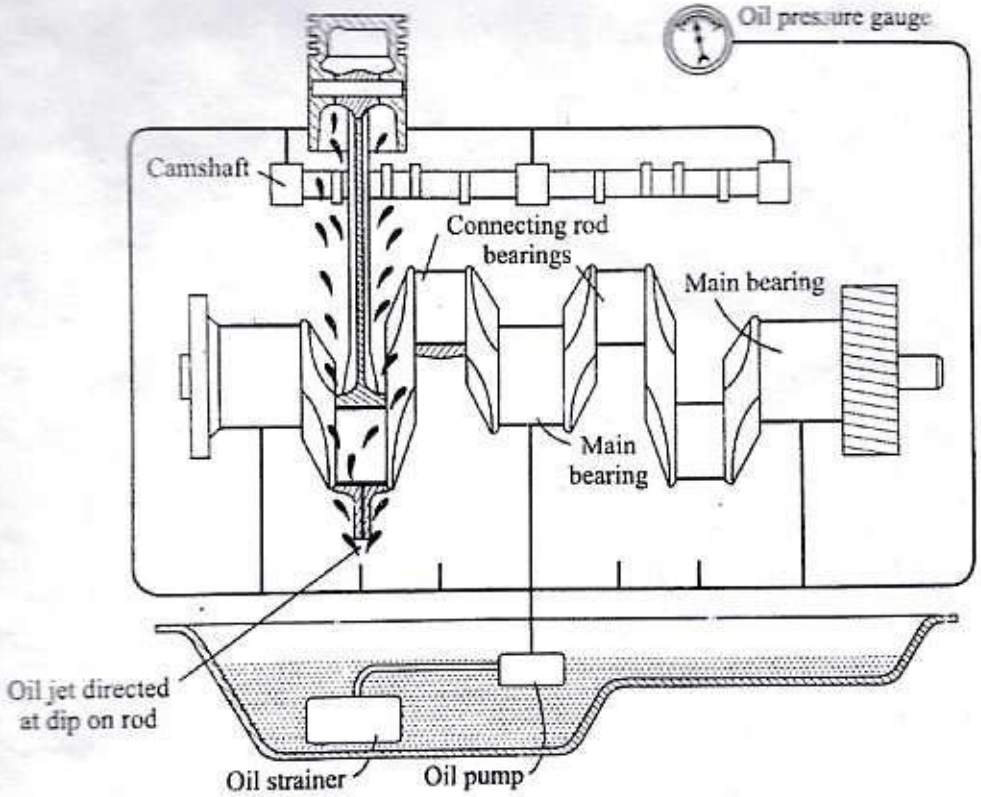
(Splash-Lubrication System)

The splash system is used for small engines. In this system the oil level in the sump is so maintained that when the connecting rod big end is at its lowest position, the dippers on the connecting rod end strike the oil in the trough which are supplied with oil from the sump by an oil pump. Due to this striking of dippers, oil splashes over various engine parts like crank pin bearings, piston skirt and rings, piston pins etc. Excess oil supplied drips back to the sump.

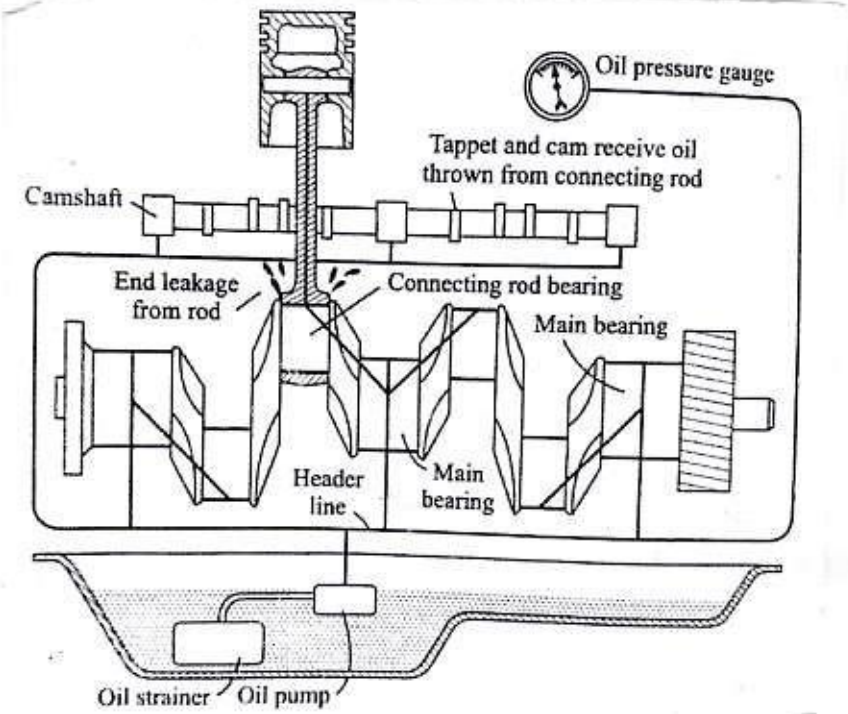
The splash system is not sufficient if the bearing loads are high. For such cases the modified splash system is used. The main & cam shaft bearings are lubricated by oil under pressure pumped by an oil pump. The other engine parts are lubricated by splash.

In the full pressure system, an oil pump is used to lubricate all parts of the engine. Drilled passages are used to lubricate connecting rod bearings. The cylinder walls, piston and piston rings are lubricated by the sprays thrown from crank shaft and connecting rod. Full pressure system is used for engines which are exposed in high engine loads.

Since the bearings are machined to a very close tolerance and are likely to be damaged if any foreign materials are allowed to enter the lubrication line, a strainer is always used in oil circuit. A gear type or rotor type pump submerged in the oil and driven by the camshaft draws oil from the sump through a strainer to prevent foreign material from entering the system. A pressure relief valve is also used to avoid very high pressure built up in case of filter clogging or if the oil is very cold or sluggish.



[Modified splash system]



(full pressure system).