Course Material
of
ME-321 (Automobile & IC Engines)
for
ICD (6^{th} Semester)

Prepared By

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Chapter -1
Introduction

INTRODUCTION

1.1 ENERGY CONVERSION

The distinctive feature of our civilization today, one that makes it different from all others, is the wide use of mechanical power. At one time, the primary source of power for the work of peace or war was chiefly man's muscles. Later, animals were trained to help and afterwards the wind and the running stream were harnessed. But, the great step was taken in this direction when man learned the art of energy conversion from one form to another. The machine which does this job of energy conversion is called an engine.

1.1.1 Definition of 'Engine'

An engine is a device which transforms one form of energy into another form. However, while transforming energy from one form to another, the efficiency of conversion plays an important role. Normally, most of the engines convert thermal energy into mechanical work and therefore they are called 'heat engines'.

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1.1.2 Definition of 'Heat Engine'

Heat engine is a device which transforms the chemical energy of a fuel into thermal energy and utilizes this thermal energy to perform useful work. Thus, thermal energy is converted to mechanical energy in a heat engine.

Heat engines can be broadly classified into two categories:

(i) Internal Combustion Engines (IC Engines)

(ii) External Combustion Engines (EC Engines)

1.1.3 Classification and Some Basic Details of Heat Engines

Engines whether Internal Combustion or External Combustion are of two types, viz.,

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(i) Rotary engines

(ii) Reciprocating engines

A detailed classification of heat engines is given in Fig.1.1. Of the various types of heat engines, the most widely used ones are the reciprocating internal combustion engine, the gas turbine and the steam turbine. The steam engine is rarely used nowadays. The reciprocating internal combustion engine enjoys some advantages over the steam turbine due to the absence of heat exchangers in the passage of the working fluid (boilers and condensers in steam turbine plant). This results in a considerable mechanical simplicity and improved power plant efficiency of the internal combustion engine.

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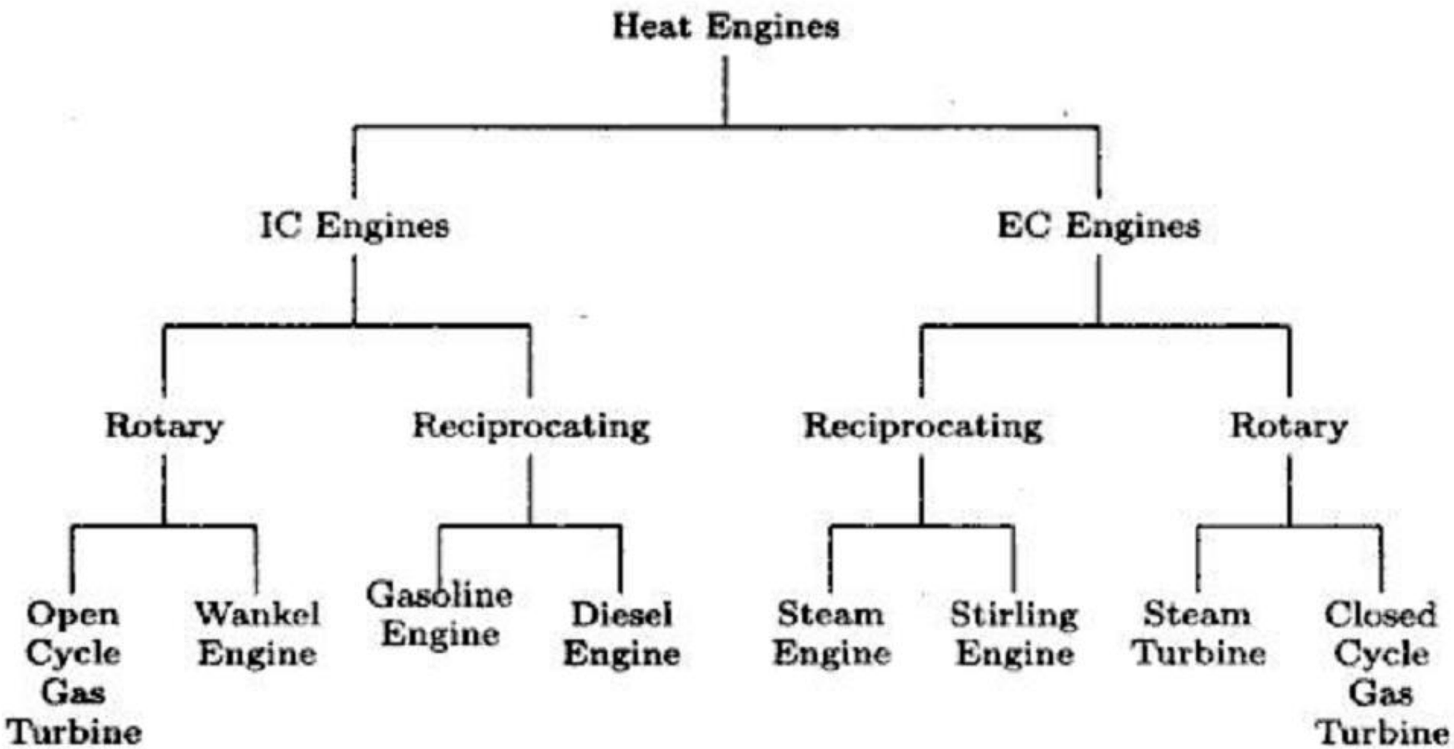

Fig. 1.1 Classification of Heat Engines

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Another advantage of the reciprocating internal combustion engine over the other two types is that all its components work at an average temperature which is much below the maximum temperature of the working fluid in the cycle. This is because the high temperature of the working fluid in the cycle persists only for a very small fraction of the cycle time. Therefore, very high working fluid temperatures can be employed resulting in higher thermal efficiency.

Further, in internal combustion engines, higher thermal efficiency can be obtained with moderate maximum working pressure of the fluid in the cycle, and therefore, the weight to power ratio is less than that of the steam turbine plant. Also, it has been possible to develop reciprocating internal combustion engines of very small power output (power output of even a fraction of a kilowatt) with reasonable thermal efficiency and cost.

The main disadvantage of this type of engine is the problem of vibration caused by the reciprocating components. Also, it is not possible to use a variety of fuels in these engines. Only liquid or gaseous fuels of given specification can be efficiently used. These fuels are relatively more expensive.

Considering all the above factors the reciprocating internal combustion engines have been found suitable for use in automobiles, motor-cycles and

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scooters, power boats, ships, slow speed aircraft, locomotives and power units of relatively small output.

1.1.4 External Combustion and Internal Combustion Engines

External combustion engines are those in which combustion takes place outside the engine whereas in internal combustion engines combustion takes place within the engine. For example, in a steam engine or a steam turbine, the heat generated due to the combustion of fuel is employed to generate high pressure steam which is used as the working fluid in a reciprocating engine or a turbine.

In case of gasoline or diesel engines, the products of combustion generated by the combustion of fuel and air within the cylinder form the working fluid.

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1.2 BASIC ENGINE COMPONENTS AND NOMENCLATURE

Even though reciprocating internal combustion engines look quite simple, they are highly complex machines. There are hundreds of components which have to perform their functions satisfactorily to produce output power. There are two types of engines, viz., spark-ignition (SI) and compression-ignition (CI) engine . Let us now go through the important engine components and the nomenclature associated with an engine.

1.2.1 Engine Components

A cross section of a single cylinder spark-ignition engine with overhead valves is shown in Fig.1.2. The major components of the engine and their functions are briefly described below.

Cylinder Block : The cylinder block is the main supporting structure for the various components. The cylinder of a multicylinder engine are cast as a single unit, called cylinder block. The cylinder head is mounted on the cylinder block. The cylinder head and cylinder block are provided with water jackets in the case of water cooling or with cooling fins in the case of air cooling. Cylinder head gasket is incorporated between the cylinder block and cylinder head. The cylinder head is held tight to the cylinder block by number of bolts or studs. The bottom portion of the cylinder block is called crankcase. A cover called crankcase which becomes a sump for lubricating oil is fastened to the bottom of the crankcase. The inner surface of the cylinder block which is machined and finished accurately to cylindrical shape is called bore or face.

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Cylinder : As the name implies it is a cylindrical vessel or space in which the piston makes a reciprocating motion. The varying volume created in the cylinder during the operation of the engine is filled with the working fluid and subjected to different thermodynamic processes. The cylinder is supported in the cylinder block.

Piston : It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system. It fits perfectly (snugly) into the cylinder providing a gas-tight space with the piston rings and the lubricant. It forms the first link in transmitting the gas forces to the output shaft.

Combustion Chamber : The space enclosed in the upper part of the cylinder, by the cylinder head and the piston top during the combustion process, is called the combustion chamber. The combustion of fuel and the consequent release of thermal energy results in the building up of pressure in this part of the cylinder.

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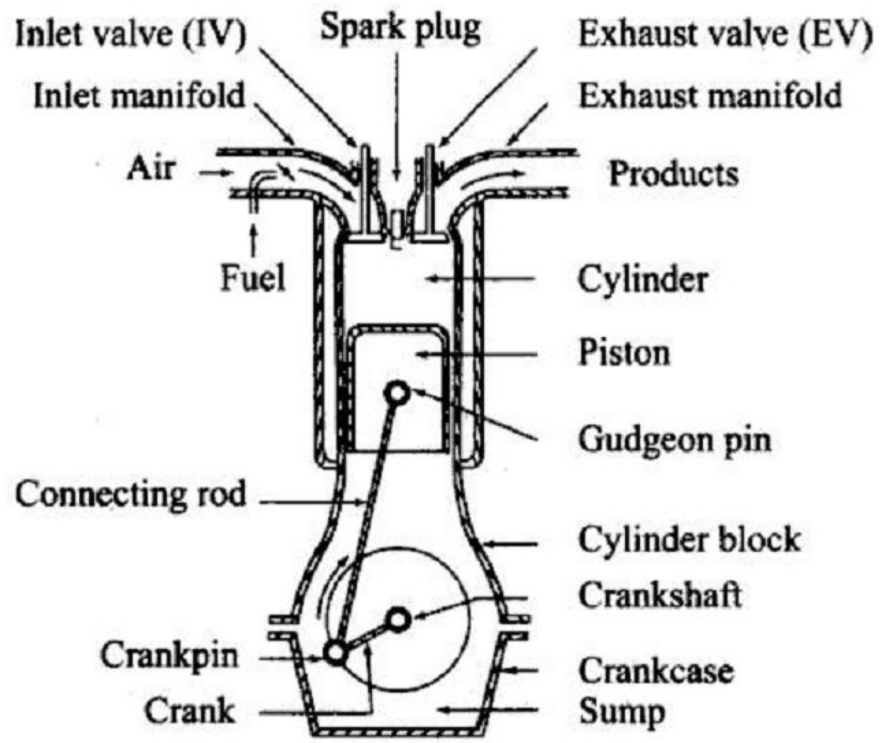

Fig. 1.2 Cross-section of a Spark-Ignition Engine

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Inlet Manifold : The pipe which connects the intake system to the inlet valve of the engine and through which air or air-fuel mixture is drawn into the cylinder is called the inlet manifold.

Exhaust Manifold : The pipe which connects the exhaust system to the exhaust valve of the engine and through which the products of combustion escape into the atmosphere is called the exhaust manifold.

Inlet and Exhaust Valves : Valves are commonly mushroom shaped poppet type. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) and for discharging the products of combustion (exhaust valve) from the cylinder.

Spark Plug : It is a component to initiate the combustion process in Spark-Ignition (SI) engines and is usually located on the cylinder head.

Connecting Rod : It interconnects the piston and the crankshaft and transmits the gas forces from the piston to the crankshaft. The two ends of the connecting rod are called as small end and the big end (Fig.1.3). Small end is connected to the piston by gudgeon pin and the big end is connected to the crankshaft by crankpin.

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Crankshaft : It converts the reciprocating motion of the piston into useful rotary motion of the output shaft. In the crankshaft of a single cylinder engine there are a pair of crank arms and balance weights. The balance weights are provided for static and dynamic balancing of the rotating system. The crankshaft is enclosed in a crankcase.

Piston Rings : Piston rings, fitted into the slots around the piston, provide a tight seal between the piston and the cylinder wall thus preventing leakage of combustion gases (Fig.1.3).

Gudgeon Pin : It forms the link between the small end of the connecting rod and the piston.

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Camshaft : The camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. This shaft also provides the drive to the ignition system. The camshaft is driven by the crankshaft through timing gears.

Cams : These are made as integral parts of the camshaft and are designed in such a way to open the valves at the correct timing and to keep them open for the necessary duration.

Fly Wheel : The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates causing a change in the angular velocity of the shaft. In order to achieve a uniform torque an inertia mass in the form of a wheel is attached to the output shaft and this wheel is called the flywheel.

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1.2.2 Nomenclature

Cylinder Bore (d) **:** The nominal inner diameter of the working cylinder is called the cylinder bore and is designated by the letter d and is usually expressed in millimeter (mm).

Piston Area (A) **:** The area of a circle of diameter equal to the cylinder bore is called the piston area and is designated by the letter A and is usually expressed in square centimeter (cm^2).

Stroke (L) **:** The nominal distance through which a working piston moves between two successive reversals of its direction of motion is called the stroke and is designated by the letter L and is expressed usually in millimeter (mm).

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Stroke to Bore Ratio : L/d ratio is an important parameter in classifying the size of the engine.

If $d < L$, it is called under-square engine. If $d = L$, it is called square engine. If $d > L$, it is called over-square engine.

An over-square engine can operate at higher speeds because of larger bore and shorter stroke.

Dead Centre : The position of the working piston and the moving parts which are mechanically connected to it, at the moment when the direction of the piston motion is reversed at either end of the stroke is called the dead centre. There are two dead centres in the engine as indicated in Fig.1.3.

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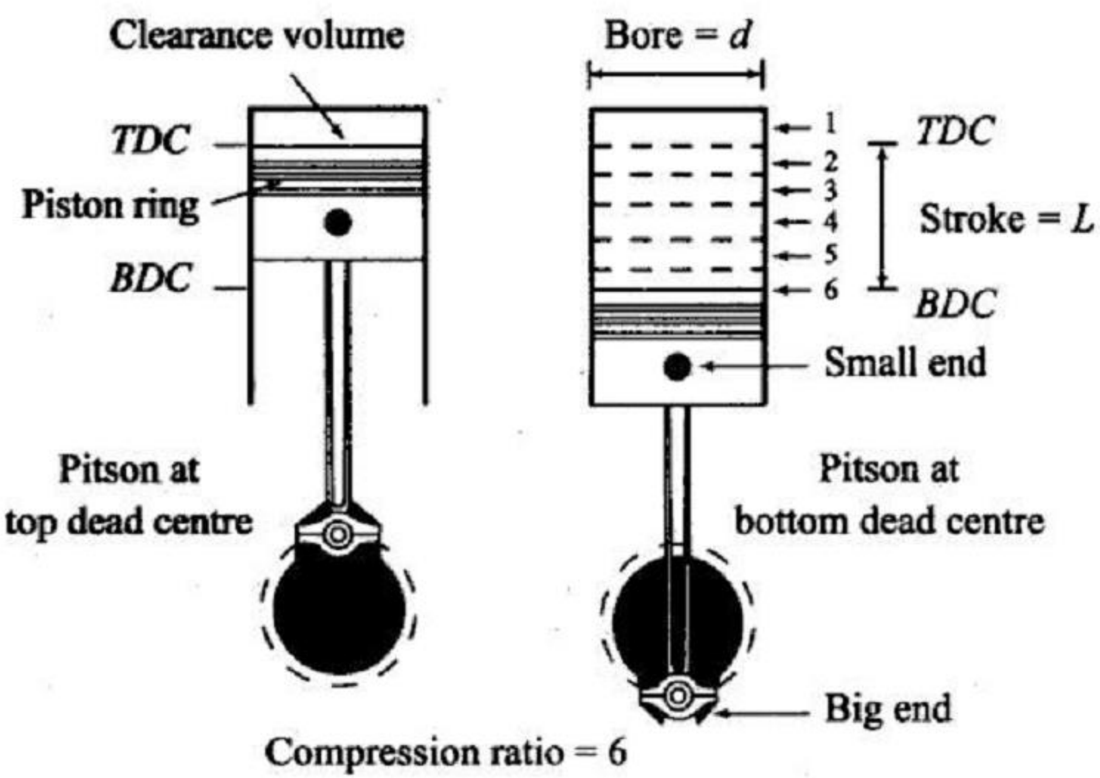

Fig. 1.3 Top and Bottom Dead Centres

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They are:

(i) Top Dead Centre (ii) Bottom Dead Centre

(i) *Top Dead Centre* (TDC) : It is the dead centre when the piston is farthest from the crankshaft. It is designated as TDC for vertical engines and Inner Dead Centre (IDC) for horizontal engines.

(ii) *Bottom Dead Centre* (BDC) : It is the dead centre when the piston is nearest to the crankshaft. It is designated as BDC for vertical engines and Outer Dead Centre (ODC) for horizontal engines.

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Displacement or Swept Volume (V_s) **:** The nominal volume swept by the working piston when travelling from one dead centre to the other is called the displacement volume. It is expressed in terms of cubic centimeter (cc) and given by

$$V_s = A \times L \quad = \quad \frac{\pi}{4} d^2 L \qquad (1.1)$$

Cubic Capacity or Engine Capacity : The displacement volume of a cylinder multiplied by number of cylinders in an engine will give the cubic capacity or the engine capacity. For example, if there are K cylinders in an engine, then

$$\text{Cubic capacity} = V_s \times K$$

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Clearance Volume (V_C) **:** The nominal volume of the combustion chamber above the piston when it is at the top dead centre is the clearance volume. It is designated as V_C and expressed in cubic centimeter (cc).

Compression Ratio (r) **:** It is the ratio of the total cylinder volume when the piston is at the bottom dead centre, V_T, to the clearance volume, V_C.

It is designated by the letter r.

$$r = \frac{V_T}{V_C} = \frac{V_C + V_s}{V_C} = 1 + \frac{V_s}{V_C}$$

1.3 THE WORKING PRINCIPLE OF ENGINES

If an engine is to work successfully then it has to follow a cycle of operations in a sequential manner. The sequence is quite rigid and cannot be changed. In the following sections the working principle of both SI and CI engines is described. Even though both engines have much in common there are certain fundamental differences.

The credit of inventing the spark-ignition engine goes to Nicolaus A. Otto (1876) whereas compression-ignition engine was invented by Rudolf Diesel (1892). Therefore, they are often referred to as Otto engine and Diesel engine.

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1.3.1 Four-Stroke Spark-Ignition Engine

In a four-stroke engine, the cycle of operations is completed in four strokes of the piston or two revolutions of the crankshaft. During the four strokes, there are five events to be completed, viz., suction, compression, combustion, expansion and exhaust. Each stroke consists of 180° of crankshaft rotation and hence a four-stroke cycle is completed through 720° of crank rotation. The cycle of operation for an ideal four-stroke SI engine consists of the following four strokes : (i) suction or intake stroke; (ii) compression stroke; (iii) expansion or power stroke and (iv) exhaust stroke.

The details of various processes of a four-stroke spark-ignition engine with overhead valves are shown in Fig.1.4 (a-d). When the engine completes all the five events under ideal cycle mode, the *p-V* diagram will be as shown in Fig.1.5.

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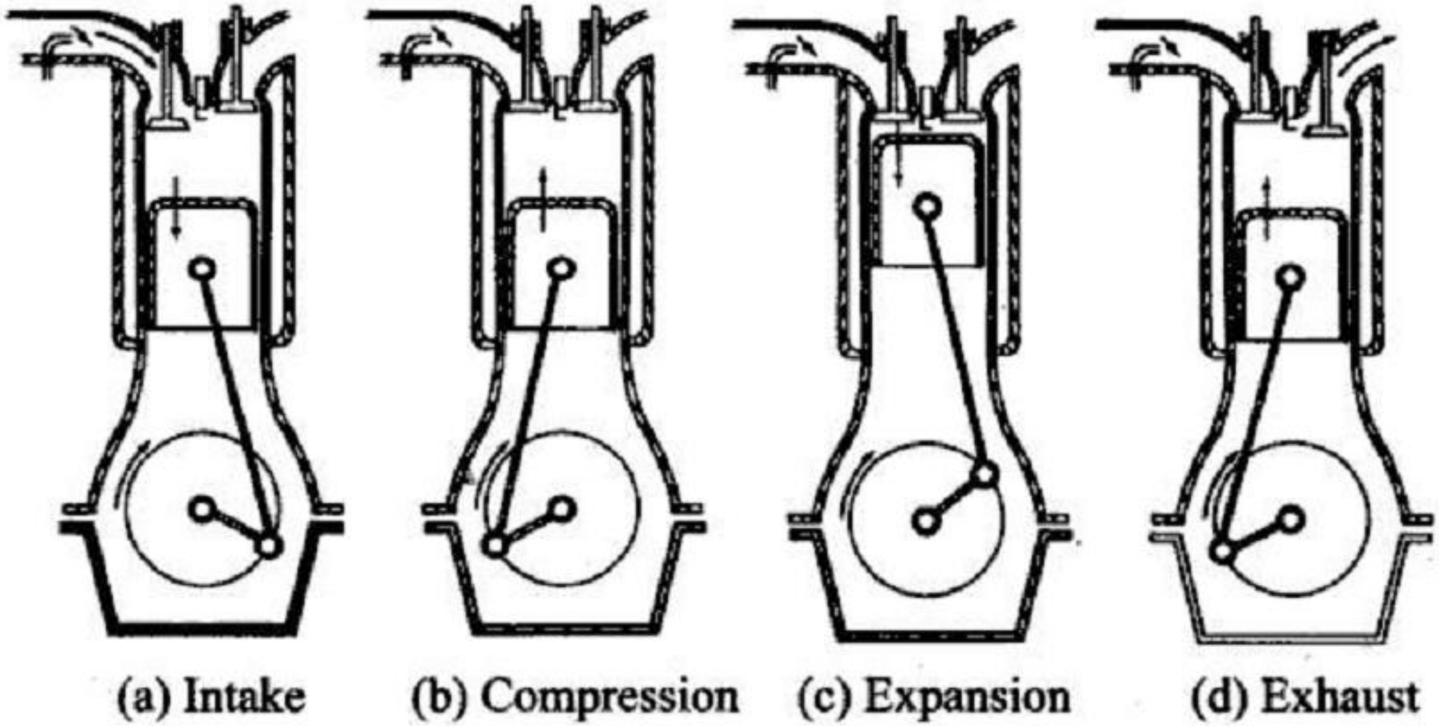

Fig. 1.4 Working Principle of a Four-Stroke SI Engine

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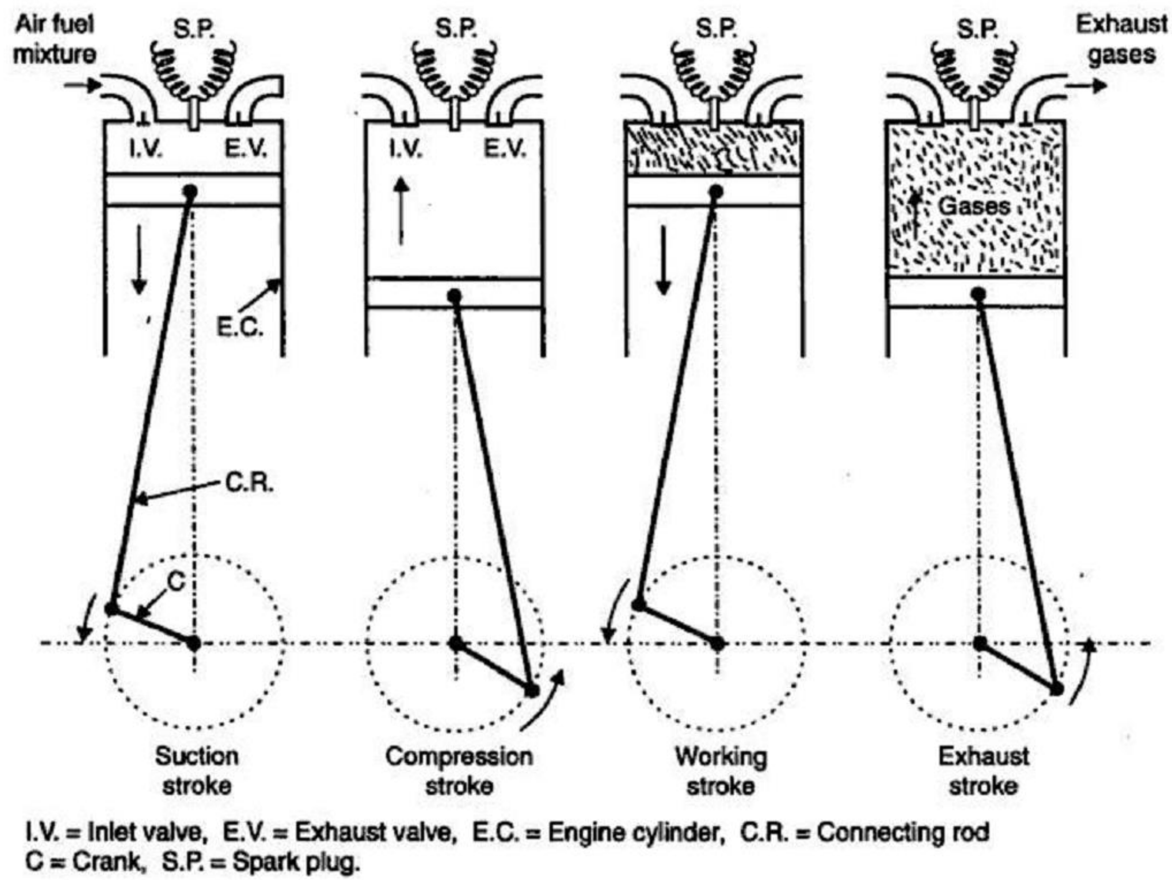

Fig. 2.34. Four stroke Otto cycle engine.

Diagram for reference only

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(i) *Suction or Intake Stroke :* Suction stroke 0→1 (Fig.1.5) starts when the piston is at the top dead centre and about to move downwards. The inlet valve is open at this time and the exhaust valve is closed, Fig.1.4(a). Due to the suction created by the motion of the piston towards the bottom dead centre, the charge consisting of fuel-air mixture is drawn into the cylinder. When the piston reaches the bottom dead centre the suction stroke ends and the inlet valve closes.

(ii) *Compression Stroke :* The charge taken into the cylinder during the suction stroke is compressed by the return stroke of the piston 1→2, (Fig.1.5). During this stroke both inlet and exhaust valves are in closed position, Fig.1.4(b). The mixture which fills the entire cylinder volume is now compressed into the clearance volume. At the end of the compression stroke the mixture is ignited with the help of a spark plug located on the cylinder head. In ideal engines it is assumed that burning takes place instantaneously when the piston is at the top dead centre and hence the burning process can be approximated as heat addition at constant volume. During the burning process the chemical energy of the fuel is converted into heat energy producing a temperature rise of about 2000 °C (process 2→3), Fig.1.5. The pressure at the end of the combustion process is considerably increased due to the heat release from the fuel.

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(iii) *Expansion or Power Stroke :* The high pressure of the burnt gases forces the piston towards the *BDC*, (stroke 3→4) Fig.1.5. Both the valves are in closed position, Fig.1.4(c). Of the four-strokes only during this stroke power is produced. Both pressure and temperature decrease during expansion.

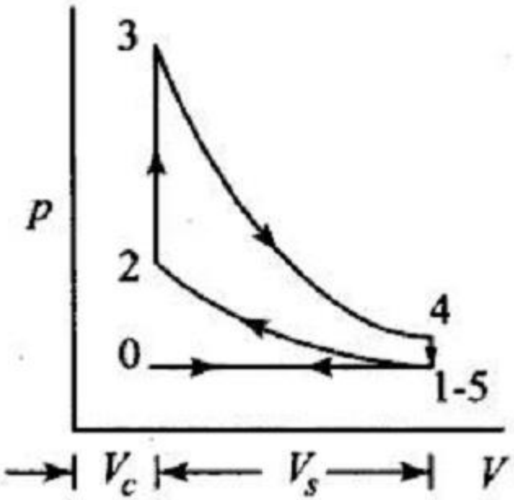

Fig. 1.5 Ideal p-V Diagram of a Four-Stroke SI Engine

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(iv) *Exhaust Stroke :* At the end of the expansion stroke the exhaust valve opens and the inlet valve remains closed, Fig.1.4(d). The pressure falls to atmospheric level a part of the burnt gases escape. The piston starts moving from the bottom dead centre to top dead centre (stroke 5→0), Fig.1.5 and sweeps the burnt gases out from the cylinder almost at atmospheric pressure. The exhaust valve closes when the piston reaches *TDC*. at the end of the exhaust stroke and some residual gases trapped in the clearance volume remain in the cylinder.

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These residual gases mix with the fresh charge coming in during the following cycle, forming its working fluid. Each cylinder of a four-stroke engine completes the above four operations in two engine revolutions, one revolution of the crankshaft occurs during the suction and compression strokes and the second revolution during the power and exhaust strokes. Thus for one complete cycle there is only one power stroke while the crankshaft turns by two revolutions. For getting higher output from the engine the heat release (process 2→3) should be as high as possible and the heat rejection (process 3→4) should be as small as possible. So one should be careful in drawing the ideal p-V diagram (Fig.1.5).

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1.3.2 Four-Stroke Compression-Ignition Engine

The four-stroke CI engine is similar to the four-stroke SI engine but it operates at a much higher compression ratio. The compression ratio of an SI engine is between 6 and 10 while for a CI engine it is from 16 to 20. In the CI engine during suction stroke, air, instead of a fuel-air mixture, is inducted. Due to the high compression ratio employed, the temperature at the end of the compression stroke is sufficiently high to self ignite the fuel which is injected into the combustion chamber. In CI engines, a high pressure fuel pump and an injector are provided to inject the fuel into the combustion chamber. The carburettor and ignition system necessary in the SI engine are not required in the CI engine.

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The ideal sequence of operations for the four-stroke CI engine as shown in Fig.1.6 is as follows:

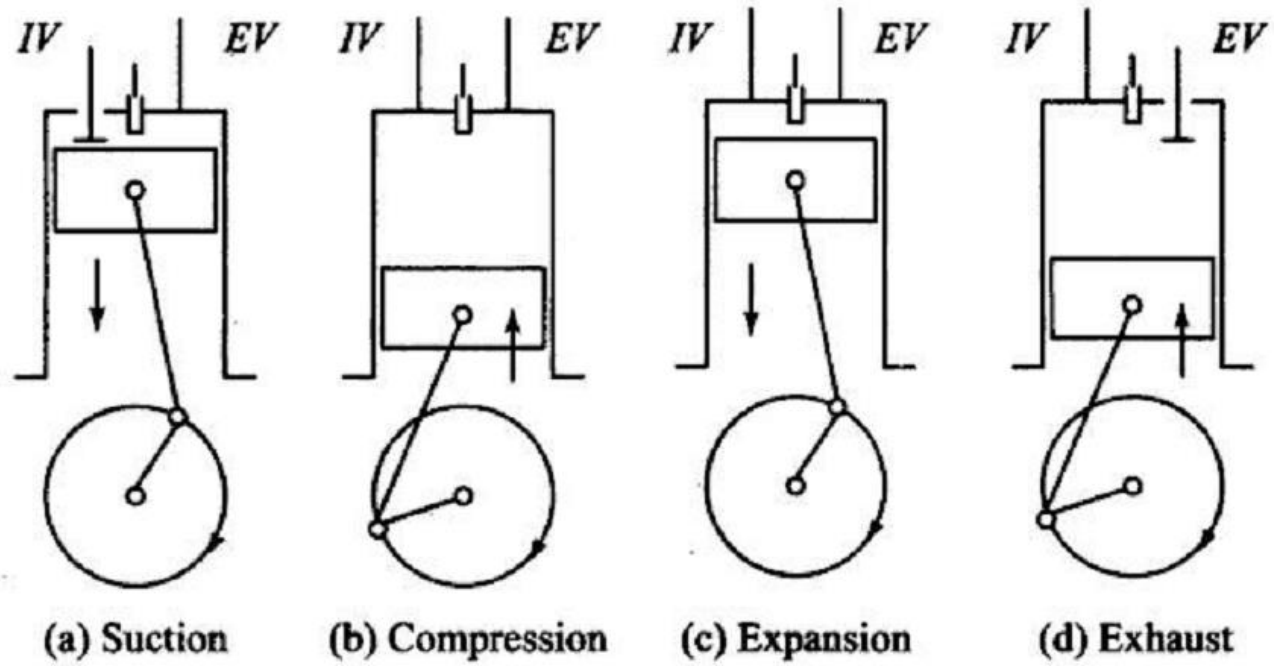

Fig. 1.6 Cycle of Operation of a CI Engine

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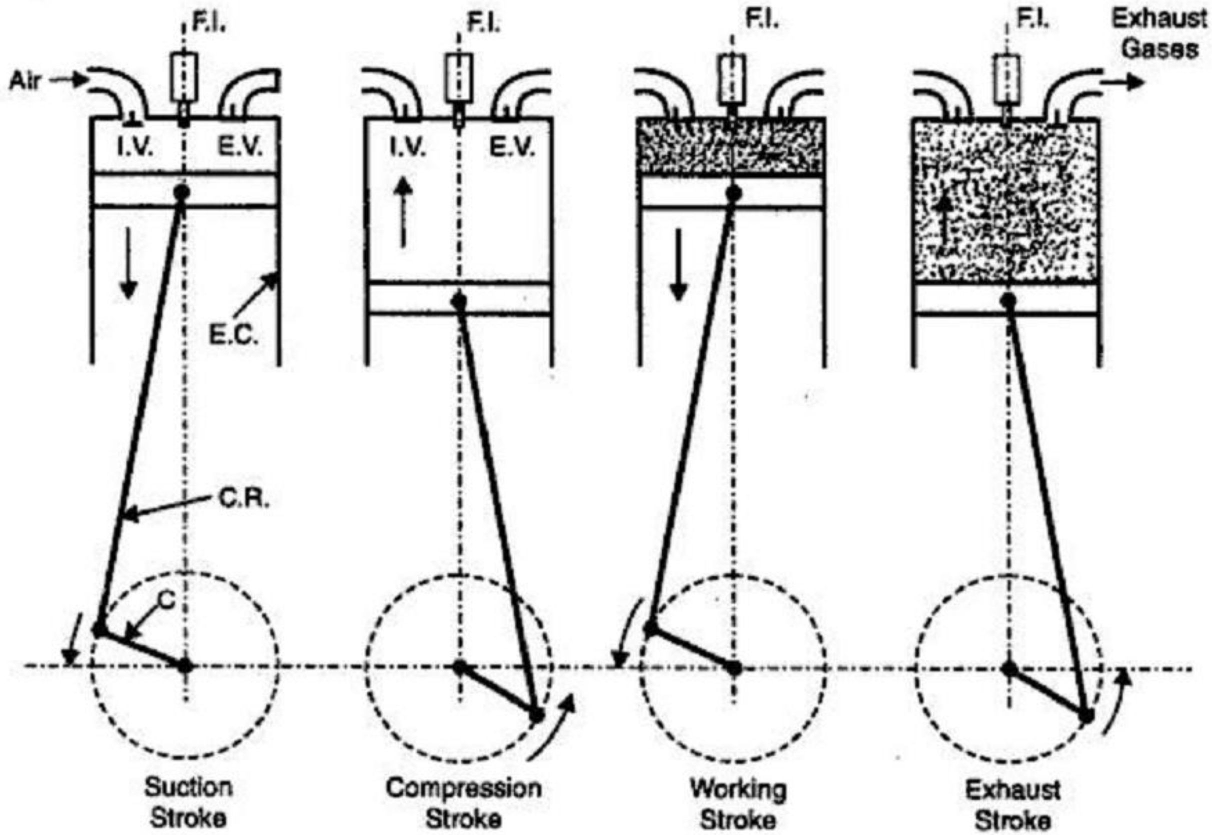

F.I. = Fuel injector, I.V. = Inlet valve, E.V. = Exhaust valve

Fig. 2.37. Four stroke Diesel cycle engine.

Diagram for reference only

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(i) *Suction Stroke :* Air alone is inducted during the suction stroke. During this stroke intake valve is open and exhaust valve is closed, Fig.1.6(a).

(ii) *Compression Stroke :* Air inducted during the suction stroke is compressed into the clearance volume. Both valves remain closed during this stroke, Fig.1.6(b).

(iii) *Expansion Stroke :* Fuel injection starts nearly at the end of the compression stroke. The rate of injection is such that combustion maintains the pressure constant in spite of the piston movement on its expansion stroke increasing the volume. Heat is assumed to have been added at constant pressure. After the injection of fuel is completed (i.e. after cut-off) the products of combustion expand. Both the valves remain closed during the expansion stroke, Fig.1.6(c).

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(iv) *Exhaust Stroke :* The piston travelling from *BDC* to *TDC* pushes out the products of combustion. The exhaust valve is open and the intake valve is closed during this stroke, Fig.1.6(d). The ideal *p-V* diagram is shown in Fig.1.7.

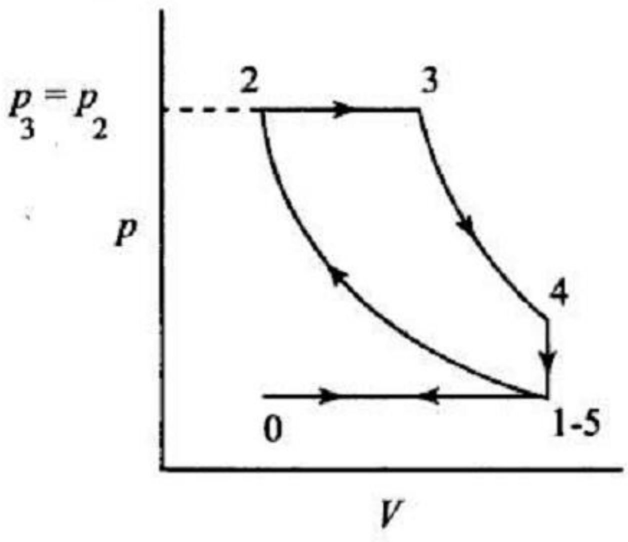

Fig. 1.7 Ideal p-V Diagram for a Four-Stroke CI Engine

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Due to higher pressures in the cycle of operations the CI engine has to be more sturdy than a SI engine for the same output. This results in a CI engine being heavier than the SI engine. However, it has a higher thermal efficiency on account of the high compression ratio (of about 18 as against about 8 in SI engines) used.

2.10. INDICATOR DIAGRAM

An indicator diagram is a graph between pressure and volume ; the former being taken on vertical axis and the latter on the horizontal axis. This is obtained by an instrument known as *indicator*. The indicator diagrams are of two types : (*a*) Theoretical or hypothetical, (*b*) Actual. The theoretical or hypothetical indicator diagram is always longer in size as compared to the actual one, since in the former losses are neglected. The ratio of the area of the actual indicator diagram to the theoretical one is called *diagram factor*.

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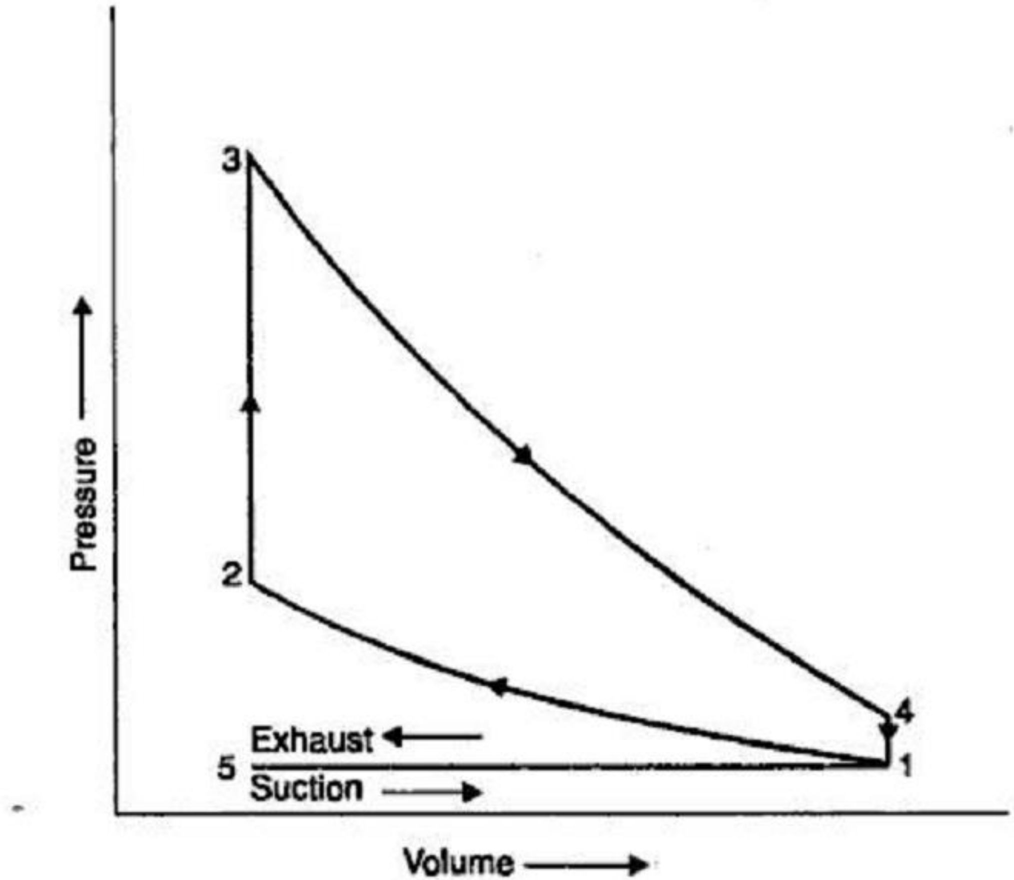

Fig. 2.35. Theoretical p-V diagram of a four stroke Otto cycle engine.

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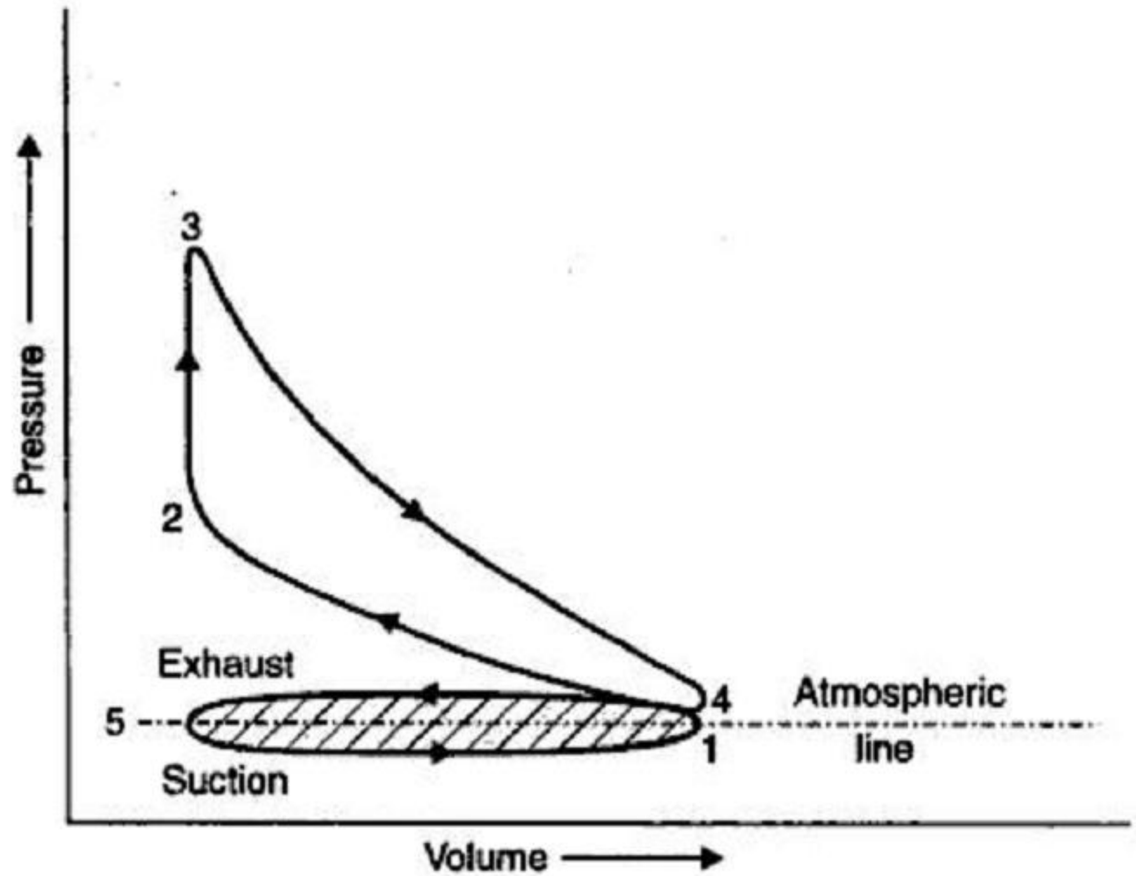

Fig. 2.36. Actual p-V diagram of a four stroke Otto cycle engine.

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Fig. 2.36 shows the actual indicator diagram of four stroke Otto cycle engine. It may be noted that line 5-1 is below the atmospheric pressure line. This is due to the fact that owing to restricted area of the inlet passages the entering fuel air mixture cannot cope with the speed of the piston. The exhaust line 4-5 is slightly above the atmospheric pressure line. This is due to restricted exhaust passages which do not allow the exhaust gases to leave the engine-cylinder quickly.

The loop which has area 4-5-1 is called *negative loop* ; it gives the pumping loss due to admission of fuel air mixture and removal of exhaust gases. The area 1-2-3-4 is the total or gross work obtained from the piston and network can be obtained by subtracting area 451 from the area 1-2-3-4.

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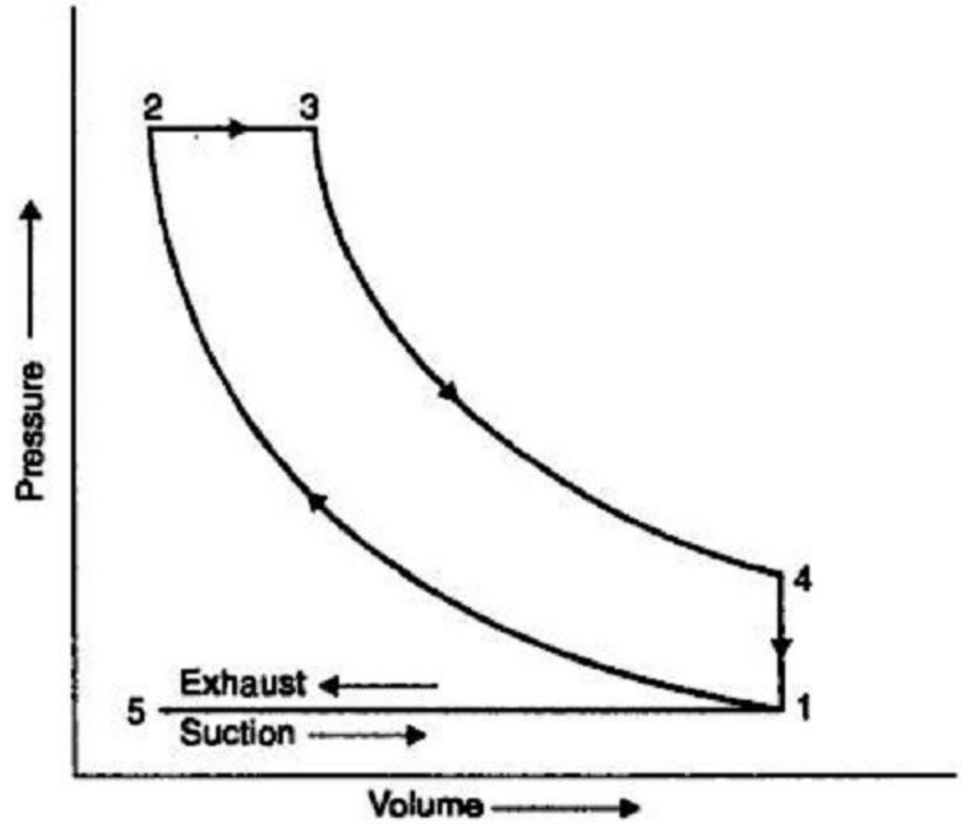

Fig. 2.38. Theoretical *p-V* diagram of a four stroke Diesel cycle.

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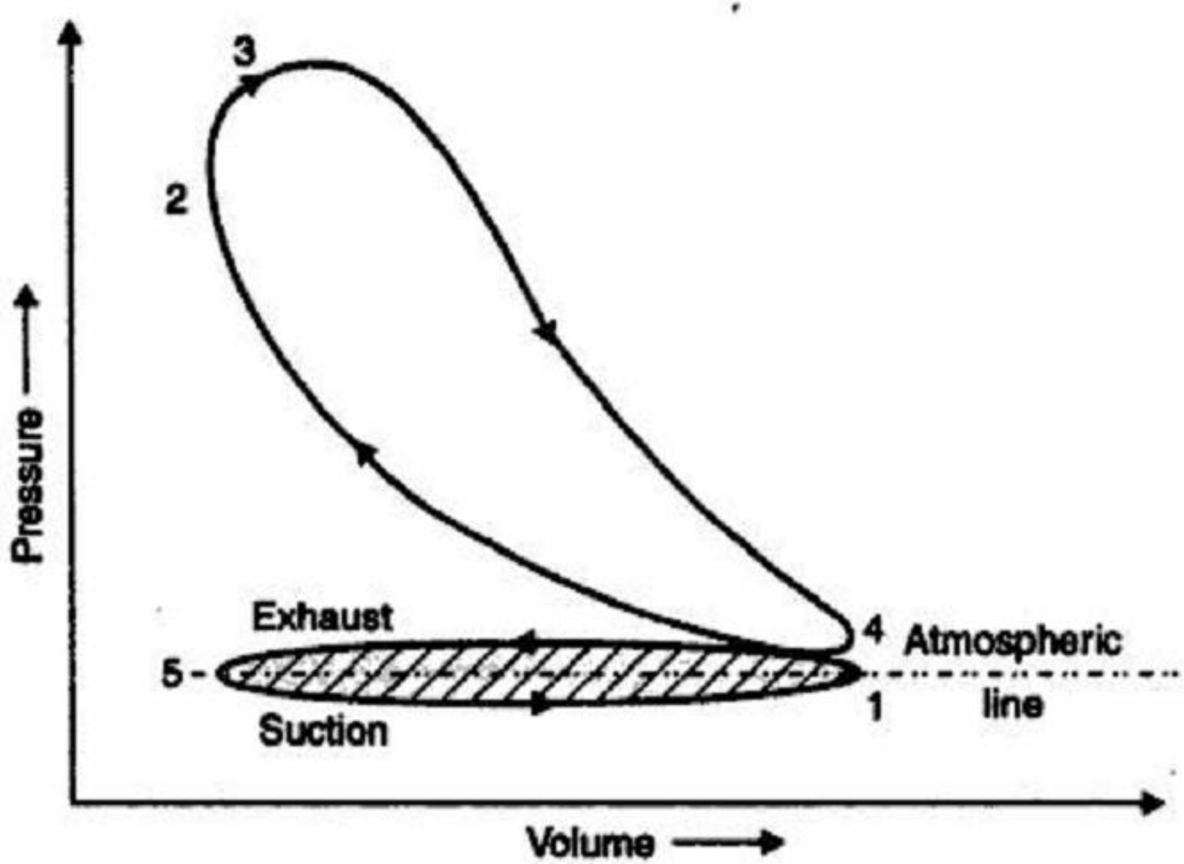

Fig. 2.39. Actual *p-V* diagram of four stroke Diesel cycle.

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Fig. 2.39 shows the actual indicator diagram for a four-stroke Diesel cycle engine. It may be noted that line 5-1 is below the atmospheric pressure line. This is due to the fact that owing to the restricted area of the inlet passages the entering air can't cope with the speed of the piston. The exhaust line 4-5 is slightly above the atmospheric line. This is because of the restricted exhaust passages which do not allow the exhaust gases to leave the engine cylinder quickly.

The loop of area 4-5-1 is called negative loop ; it gives the pumping loss due to admission of air and removal of exhaust gases. The area 1-2-3-4 is the total or gross work obtained from the piston and net work can be obtained by subtracting area 4-5-1 from area 1-2-3-4.

2.12. TWO STROKE CYCLE ENGINES

In 1878, Dugald-clerk, a British engineer introduced a cycle which could be completed in two *strokes of piston rather than four strokes* as is the case with the four stroke cycle engines. The engines using this cycle were called two stroke cycle engines. In this engine suction and exhaust strokes are eliminated. Here *instead of valves, ports are used. The exhaust gases are driven out from engine cylinder by the fresh charge of fuel entering the cylinder nearly at the end of the working stroke.*

Fig. 2.43 shows a two stroke petrol engine (used in scooters, motor cycles etc.). The cylinder L is connected to a closed crank chamber C.C. During the upward stroke of the piston M, the gases in L are compressed and at the same time fresh air and fuel (petrol) mixture enters the crank chamber through the valve V. When the piston moves downwards, V closes and the mixture in the crank chamber is compressed. Refer Fig. 2.43 (*i*), the piston is moving upwards and is compressing an explosive change which has previously been supplied to L. Ignition takes place at the end of the stroke. The piston then travels downwards due to expansion of the gases (Fig. 2.43 (*ii*)) and near the end of this stroke the piston uncovers the exhaust port (E.P.) and the burnt exhaust gases escape through this port (Fig. 2.43 (*iii*)). The transfer port (T.P.) then is uncovered immediately, and the compressed charge from the crank chamber flows into the cylinder and is deflected up-wards by the hump provided on the head of the piston. It may be noted that the incoming air petrol

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mixture helps the removal of gases from the engine-cylinder ; if, in case these exhaust gases do not leave the cylinder, the fresh charge gets diluted and efficiency of the engine will decrease. The piston then again starts moving from B.D.C. to T.D.C. and the charge gets compressed when E.P. (exhaust port) and T.P. are covered by the piston ; thus the cycle is repeated.

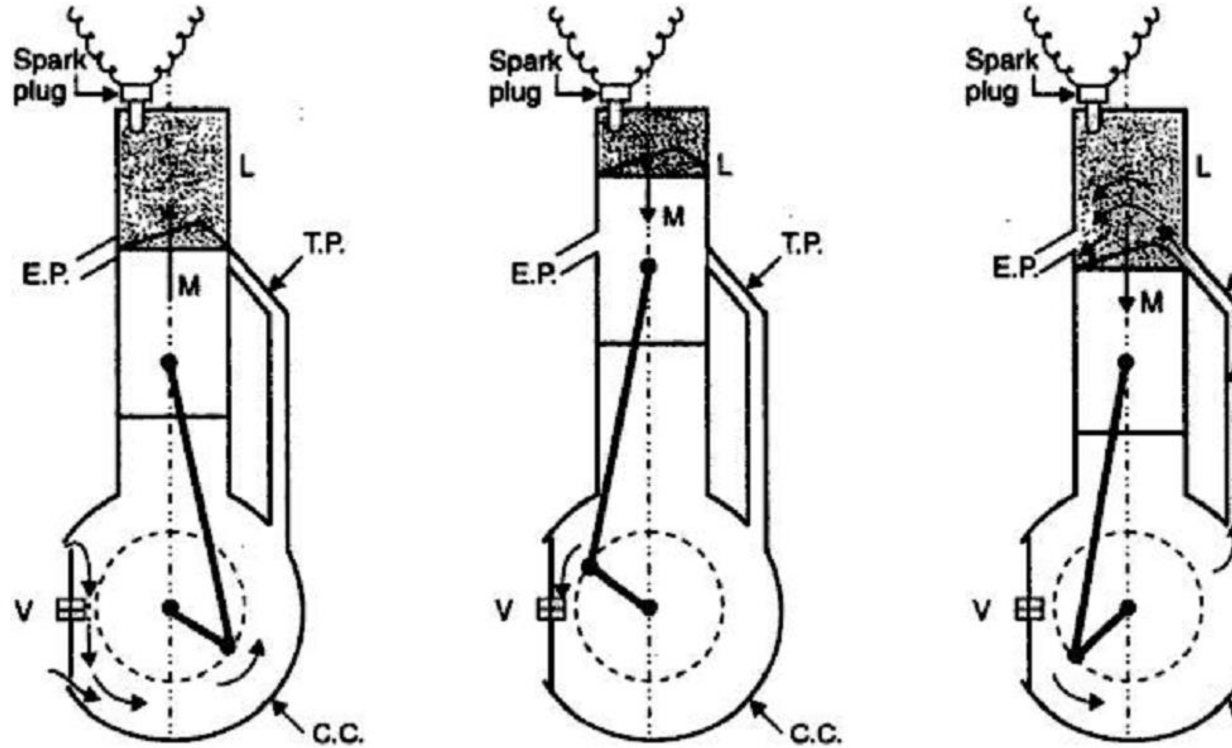

Fig. 2.43. Two stroke cycle engine.

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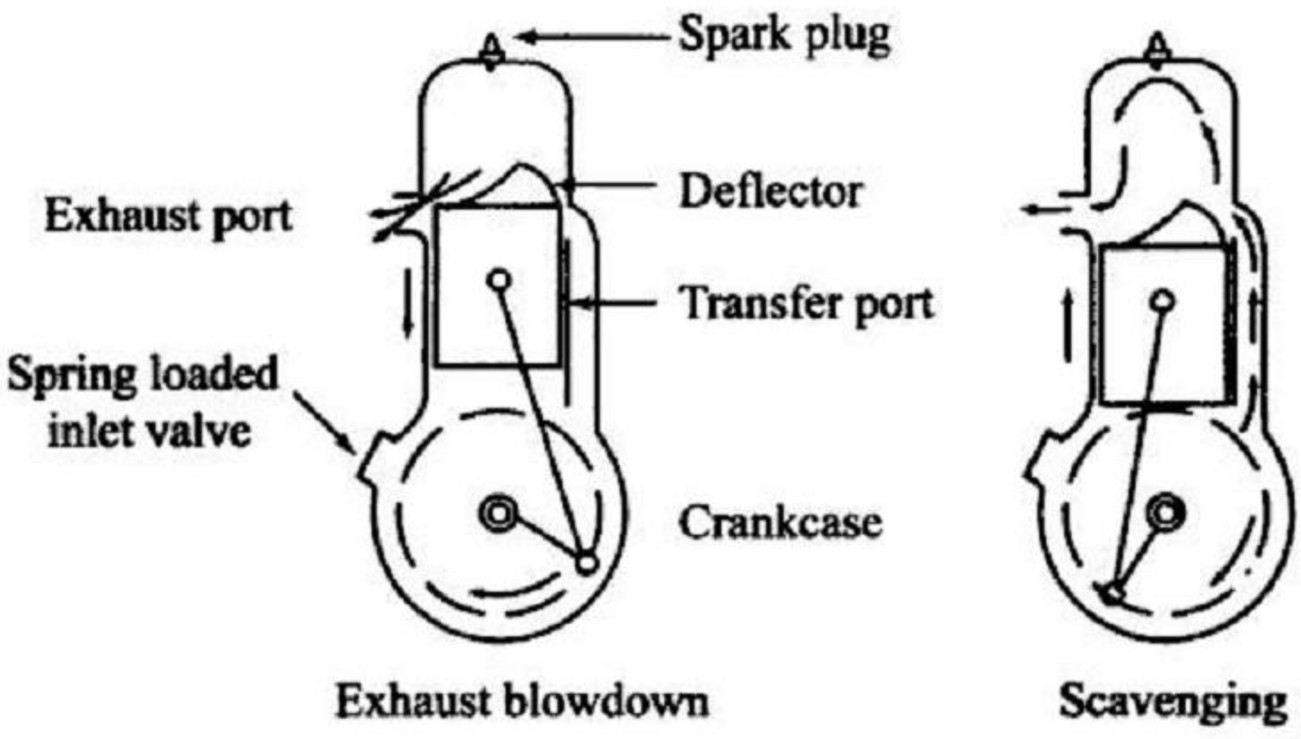

Fig. 1.8 Crankcase Scavenged Two-Stroke Engine

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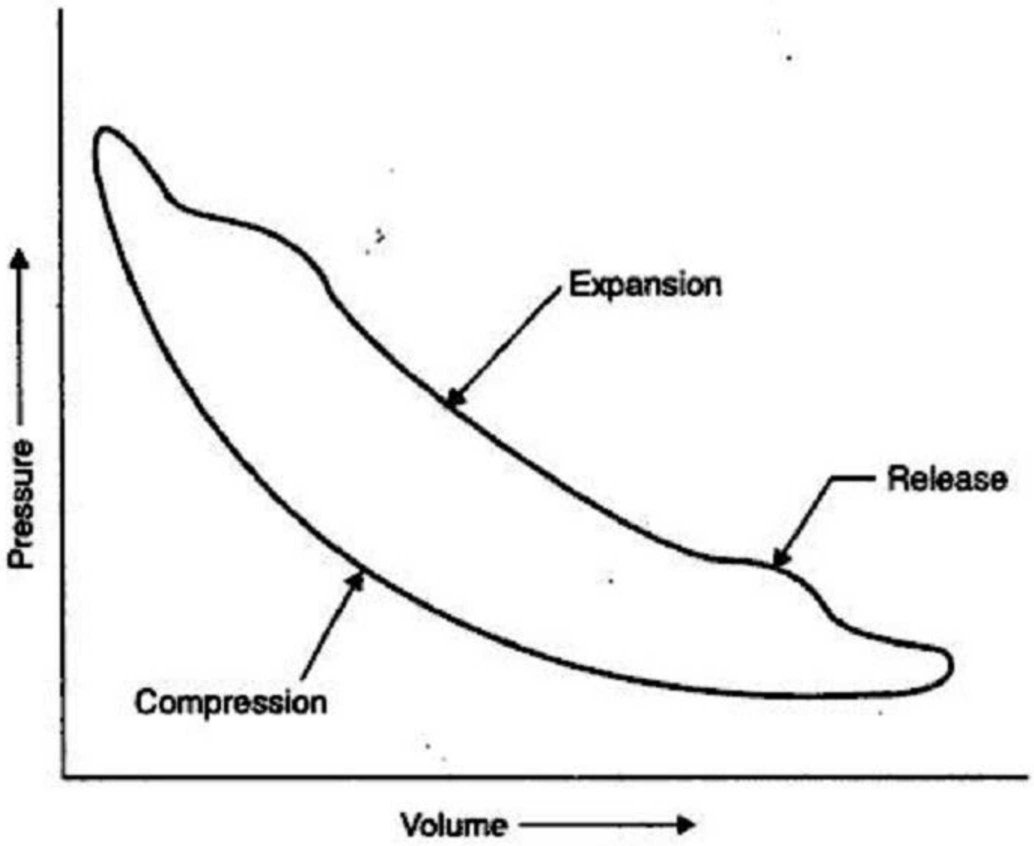

Fig. 2.44. *p-V* diagram for a two stroke cycle engine.

IC Engines

2.15. COMPARISON OF SPARK IGNITION (S.I.) AND COMPRESSION IGNITION (C.I.) ENGINES

S.No.	*Aspects*	*S.I. engines*	*C.I. engines*
1.	*Thermodynamic cycle*	Otto cycle	Diesel cycle ...... For slow speed engines Dual cycle ...... For high speed engines
2.	*Fuel used*	Petrol	Diesel.

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S.No.	Aspects	S.I. engines	C.I. engines
3.	*Air-fuel ratio*	10 : 1 to 20 : 1	18 : 1 to 100 : 1.
4.	*Compression ratio*	upto 11 ; Average value 7 to 9 ; Upper limit of compression ratio fixed by *anti-knock quality of fuel.*	12 to 24 ; Average value 15 to 18 ; Upper limit of compression ratio is limited by *thermal and mechanical stresses.*
5.	*Combustion*	Spark ignition	Compression ignition.
6.	*Fuel supply*	By carburettor ...... cheap method	By injection ...... expensive method.
7.	*Operating pressure* (*i*) Compression pressure (*ii*) Maximum pressure	7 bar to 15 bar 45 bar to 60 bar	30 bar to 50 bar 60 bar to 120 bar.
8.	*Operating speed*	High speed : 2000 to 6000 r.p.m.	Low speed : 400 r.p.m. Medium speed : 400 to 1200 r.p.m. High speed : 1200 to 3500 r.p.m.
9.	*Control of power*	Quantity governing ...... by throttle	Quality governing ...... by rack.
10.	*Calorific value*	44 MJ/kg	42 MJ/kg.
11.	*Cost of running*	high	low.
12.	*Maintenance cost*	Minor maintenance required	Major overall required but less frequently.

IC Engines

S.No.	Aspects	S.I. engines	C.I. engines
13.	*Supercharging*	Limited by *detonation*. Used only in *aircraft engines.*	Limited by *blower power and mechanical and thermal stresses. Widely used.*
14.	*Two stroke operation*	*Less suitable*, fuel loss in scavenging. But small two stroke engines are used in mopeds, scooters and motorcycles due to their *simplicity and low cost.*	No fuel loss in scavenging. *More suitable.*
15.	*High powers*	No	Yes.
16.	*Distribution of fuel*	A/F ratio is not optimum in multicylinder engines.	Excellent distribution of fuel in multicylinder engines.
17.	*Starting*	Easy, low cranking effort.	Difficult, high cranking effort.
18.	*Exhaust gas temperature*	High, due to low thermal efficiency.	Low, due to high thermal efficiency.
19.	*Weight per unit power*	Low (0.5 to 4.5 kg/kW).	High (3.3 to 13.5 kg/kW).
20.	*Initial capital cost*	Low	High due to heavy weight and study construction, costly construction, 1.25-1.5 times.
21.	*Noise and vibration*	Less	More idle noise problem.
22.	*Uses*	Mopeds, scooters, motorcycles, simple engine passenger cars, aircrafts etc.	Buses, trucks locomotives, tractors, earth moving machinery and stationary generating plants.

IC Engines

2.16. COMPARISON BETWEEN A PETROL ENGINE AND A DIESEL ENGINE

S.No.	*Petrol engine*	*Diesel engine*
1.	Air petrol mixture is sucked in the engine cylinder during suction stroke.	Only air is sucked during suction stroke.
2.	Spark plug is used.	Employs an injector.
3.	Power is produced by spark ignition.	Power is produced by compression ignition.
4.	Thermal efficiency up to 25%.	Thermal efficiency up to 40%.
5.	Occupies less space.	Occupies more space.
6.	More running cost.	Less running cost.
7.	Light in weight.	Heavy in weight.
8.	Fuel (Petrol) costlier.	Fuel (Diesel) cheaper.
9.	Petrol being volatile is dangerous.	Diesel is non-dangerous as it is non-volatile.
10.	Pre-ignition possible.	Pre-ignition not possible.
11.	Works on Otto cycle.	Works on Diesel cycle.
12.	Less dependable.	More dependable.
13.	Used in *cars* and *motor cycles*.	Used in heavy duty vehicles like *trucks*, *buses* and *heavy machinery*.

IC Engines

2.14. COMPARISON OF FOUR STROKE AND TWO STROKE CYCLE ENGINES

S.No.	Aspects	Four Stroke Cycle Engines	Two Stroke Cycle Engines
1.	*Completion of cycle*	The cycle is completed in *four strokes of the piston* or in *two revolutions of the crankshaft*. Thus one power stroke is obtained in every two revolutions of the crankshaft.	The cycle is completed in *two strokes of the piston* or in *one revolution of the crankshaft*. Thus one power stroke is obtained in each revolution of the crankshaft.
2.	*Flywheel required -heavier or lighter*	Because of the above turning-movement is not so uniform and hence *heavier* flywheel is needed.	More uniform turning movement and hence *lighter* flywheel is needed.
3.	*Power produced for same size of engine*	Again because of one power stroke for two revolutions, power produced for same size of engine is *small* or for the same power the engine is heavy and bulky.	Because of one power stroke for one revolution, power produced for same size of engine is *more* (theoretically twice, actually about 1.3 times) or for the same power the engine is light and compact.

IC Engines

S.No.	Aspects	Four Stroke Cycle Engines	Two Stroke Cycle Engines
4.	*Cooling and lubrication requirements*	Because of one power stroke in two revolutions *lesser* cooling and lubrication requirements. Lesser rate of wear and tear.	Because of one power stroke in one revolution *greater* cooling and lubrication requirement. Great rate of wear and tear.
5.	*Value and valve mechanism*	The four stroke engine *contains* valve and valve mechanism.	Two stroke engines have *no* valves but only ports (some two stroke engines are fitted with conventional exhaust valves).
6.	*Initial cost*	Because of the heavy weight and complication of valve mechanism, *higher* is the initial cost.	Because of light weight and simplicity due to absence of valve mechanism, *cheaper* in initial cost.
7.	*Volumetric efficiency*	Volumetric efficiency *more* due to more time of induction.	Volumetric efficiency *less* due to lesser time for induction.
8.	*Thermal and part-load efficiencies*	Thermal efficiency higher, part load effitiency better than two stroke cycle engine.	Thermal efficiency lower, part load efficiency lesser than four stroke cycle engine.
9.	*Applications*	Used where efficiency is important ; in *cars, buses, trucks, tractors, industrial engines, aeroplane, power generators etc.*	In two stroke petrol engine some fuel is exhausted during scavenging. Used where (*a*) *low cost*, and (*b*) *compactness and light weight important*. Two stroke (air cooled) petrol engines used in very small sizes only, *lawn movers, scooters motor cycles* (lubricating oil mixed with petrol). Two stroke diesel engines used in *very large sizes* more than 60 cm bore, for *ship propulsion* because of low weight and compactness.

IC Engines

2.17. HOW TO TELL A TWO STROKE CYCLE ENGINE FROM A FOUR STROKE CYCLE ENGINE ?

S.No.	*Distinguishing features*	*Four stroke cycle engine*	*Two stroke cycle engine*
1.	*Oil sump and oil-filter plug*	It has an oil sump and oil-filter plug.	It does not have oil sump and oil-filter plug.
2.	*Oil drains etc.*	It requires oil drains and refills periodically, just an automobile do.	In this type of engine, the oil is added to the gasoline so that a mixture of gasoline and oil passes through the carburettor and enters the crankcase with the air.
3.	*Location of muffler (exhaust silencer)*	It is installed at the head end of the cylinder at the exhaust valve location.	It is installed towards the middle of the cylinder, at the exhaust port location.
4.	Name plate	If the name plate mentions the type of oil and the crankcase capacity, or similar data, it is a four stroke cycle engine.	If the name plate tells to mix oil with the gasoline, it is a two stroke cycle engine.

Chapter-3
Performance of IC Engine

1.7 THE FIRST LAW ANALYSIS OF ENGINE CYCLE

Before a detailed thermodynamic analysis of the engine cycle is done, it is desirable to have a general picture of the energy flow or energy balance of the system so that one becomes familiar with the various performance parameters. Figure 1.13 shows the energy flow through the reciprocating engine and Fig.1.14 shows its block diagram as an open system.

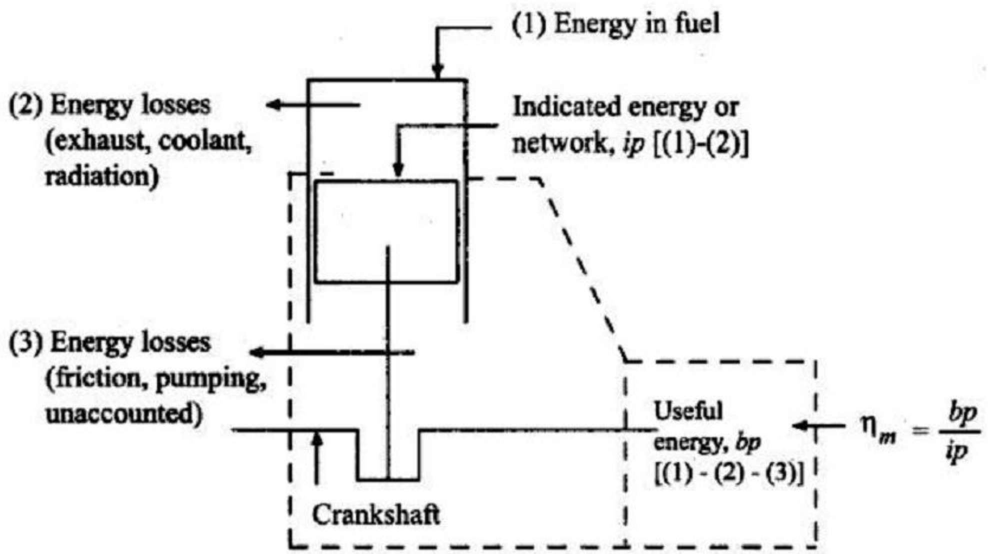


Fig. 1.13 Energy Flow through the Reciprocating Engine

Performance of IC Engine

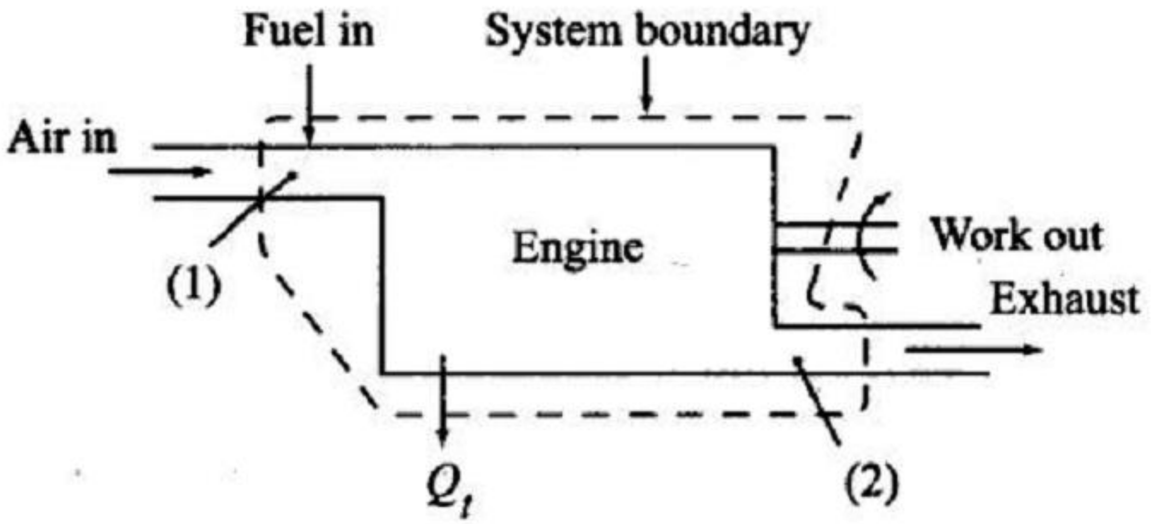


Fig. 1.14 Reciprocating Engine as an Open System

According to the first law of thermodynamics, energy can neither be created nor destroyed. It can only be converted from one form to another.

Performance of IC Engine

Therefore, there must be an energy balance of input and output to a system. In the reciprocating internal combustion engine the fuel is fed into the combustion chamber where it burns in air converting chemical energy of the fuel into heat. The liberated heat energy cannot be totally utilized for driving the piston as there are losses through the engine exhaust, to the coolant and due to radiation. The heat energy which is converted to power at this stage is called the indicated power, *ip* and it is utilized to drive the piston. The energy represented by the gas forces on the piston passes through the connecting rod to the crankshaft. In this transmission there are energy losses due to bearing friction, pumping losses etc. In addition, a part of the energy available is utilized in driving the auxiliary devices like feed pump, valve mechanisms, ignition systems etc. The sum of all these losses, expressed in units of power is termed as frictional power, fp . The remaining energy is the useful mechanical energy and is termed as the brake power, *bp* . In energy balance, generally, frictional power is not shown separately because ultimately this energy is accounted in exhaust, cooling water, radiation, etc.

Performance of IC Engine

1.8 ENGINE PERFORMANCE PARAMETERS

The engine performance is indicated by the term *efficiency*, η. Five important engine efficiencies and other related engine performance parameters are given below:

(i)	Indicated thermal efficiency	(η_{ith})
(ii)	Brake thermal efficiency	(η_{bth})
(iii)	Mechanical efficiency	(η_m)
(iv)	Volumetric efficiency	(η_v)
(v)	Relative efficiency or Efficiency ratio	(η_{rel})
(vi)	Mean effective pressure	(p_m)
(vii)	Mean piston speed	$(\bar{s}_p)$
(viii)	Specific power output	(P_s)
(ix)	Specific fuel consumption	(sfc)
(x)	Inlet-valve Mach Index	(Z)
(x)	Fuel-air or air-fuel ratio	$(F/A$ or $A/F)$
(xi)	Calorific value of the fuel	(CV)

Figure 1.15 shows the diagrammatic representation of energy distribution in an IC engine.

Performance of IC Engine

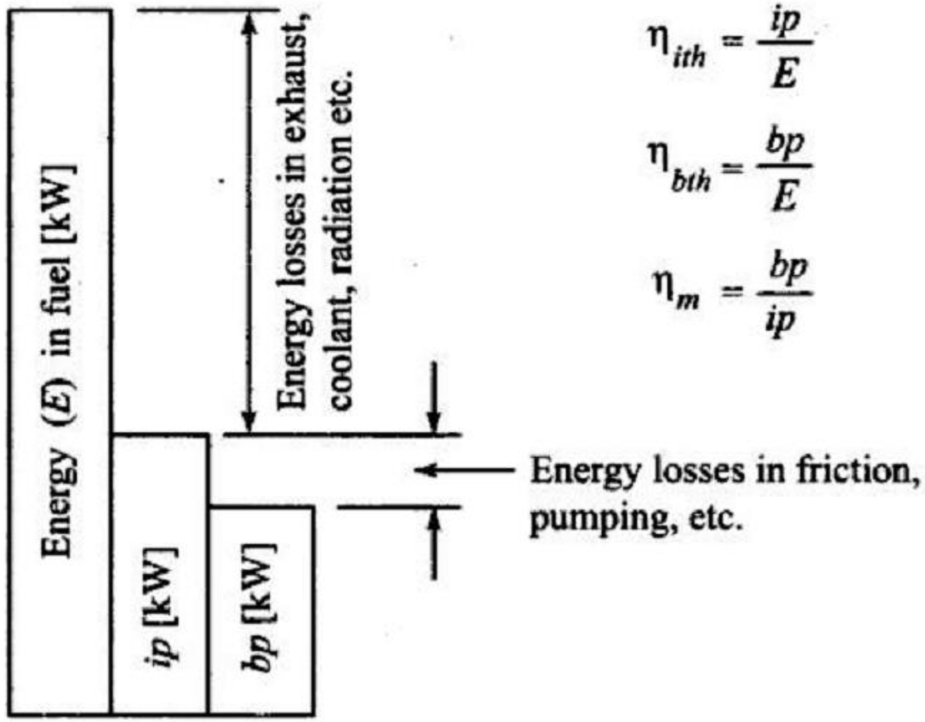
1.8.1 Indicated Thermal Efficiency (η_{ith})

Indicated thermal efficiency is the ratio of energy in the indicated power, ip, to the input fuel energy in appropriate units.

$$[ht]\eta_{ith} = \frac{ip \ [\mathrm{kJ/s}]}{\text{energy in fuel per second } [\mathrm{kJ/s}]} \quad (1.3)$$

$$= \frac{ip}{\text{mass of fuel/s} \times \text{calorific value of fuel}} \quad (1.4)$$

Performance of IC Engine



$$\eta_{ith} = \frac{ip}{E}$$

$$\eta_{bth} = \frac{bp}{E}$$

$$\eta_{m} = \frac{bp}{ip}$$

Fig. 1.15 Energy Distribution

Performance of IC Engine

1.8.2 Brake Thermal Efficiency (η_{bth})

Brake thermal efficiency is the ratio of energy in the brake power, bp, to the input fuel energy in appropriate units.

$$\eta_{bth} = \frac{bp}{\text{Mass of fuel/s} \times \text{ calorific value of fuel}} \quad (1.5)$$

1.8.3 Mechanical Efficiency (η_m)

Mechanical efficiency is defined as the ratio of brake power (delivered power) to the indicated power (power provided to the piston).

$$\eta_m = \frac{bp}{ip} = \frac{bp}{bp + fp} \quad (1.6)$$

$$fp = ip - bp \quad (1.7)$$

It can also be defined as the ratio of the brake thermal efficiency to the indicated thermal efficiency.

Performance of IC Engine

1.8.4 Volumetric Efficiency (η_v)

This is one of the very important parameters which decides the performance of four-stroke engines. Four-stroke engines have distinct suction stroke and therefore the volumetric efficiency indicates the breathing ability of the engine. It is to be noted that the utilization of the air is what going to determine the power output of the engine. Hence, an engine must be able to take in as much air as possible.

Volumetric efficiency is defined as the volume flow rate of **air** into the intake system divided by the rate at which the volume is displaced by the system.

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_{disp} N/2} \qquad (1.8)$$

where ρ_a is the inlet density

Performance of IC Engine

An alternative equivalent definition for volumetric efficiency is

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_d} \tag{1.9}$$

It is to be noted that irrespective of the engine whether SI, CI or gas engine, *volumetric rate of air flow is what to be taken into account* and not the mixture flow.

If ρ_a is taken as the atmospheric air density, then η_v represents the pumping performance of the entire inlet system. If it is taken as the air density in the inlet manifold, then η_v represents the pumping performance of the inlet port and valve only.

The normal range of volumetric efficiency at full throttle for SI engines is between 80 to 85% where as for CI engines it is between 85 to 90%. Gas engines have much lower volumetric efficiency since gaseous fuel displaces air and therefore the breathing capacity of the engine is reduced.

Performance of IC Engine

1.8.6 Mean Effective Pressure (p_m)

Mean effective pressure is the average pressure inside the cylinders of an internal combustion engine based on the calculated or measured power output. It increases as manifold pressure increases. For any particular engine, operating at a given speed and power output, there will be a specific indicated mean effective pressure, *imep*, and a corresponding brake mean effective pressure, *bmep*. They are derived from the indicated and brake power respectively. For derivation see Chapter 17. Indicated power can be shown to be

$$ip = \frac{p_{im} L A n K}{60 \times 1000} \qquad (1.11)$$

then, the indicated mean effective pressure can be written as

Performance of IC Engine

$$p_{im} = \frac{60000 \times ip}{LAnK} \quad (1.12)$$

Similarly, the brake mean effective pressure is given by

$$p_{bm} = \frac{60000 \times bp}{LAnK} \quad (1.13)$$

where
ip = indicated power (kW)
p_{im} = indicated mean effective pressure (N/m^2)
L = length of the stroke (m)
A = area of the piston (m^2)
N = speed in revolutions per minute (rpm)
n = Number of power strokes
$N/2$ for 4-stroke and N for 2-stroke engines
K = number of cylinders

Another way of specifying the indicated mean effective pressure p_{im} is from the knowledge of engine indicator diagram (p-V diagram). In this case, p_{im}, may be defined as

$$p_{im} = \frac{\text{Area of the indicator diagram}}{\text{Length of the indicator diagram}}$$

where the length of the indicator diagram is given by the difference between the total volume and the clearance volume.

Performance of IC Engine

1.8.9 Specific Fuel Consumption (sfc)

The fuel consumption characteristics of an engine are generally expressed in terms of specific fuel consumption in kilograms of fuel per kilowatt-hour. It is an important parameter that reflects how good the engine performance is. It is inversely proportional to the thermal efficiency of the engine.

$$\text{sfc} = \frac{\text{Fuel consumption per unit time}}{\text{Power}} \tag{1.16}$$

Brake specific fuel consumption and indicated specific fuel consumption, abbreviated as $bsfc$ and $isfc$, are the specific fuel consumptions on the basis of bp and ip respectively.

Performance of IC Engine

1.8.11 Fuel-Air (F/A) or Air-Fuel Ratio (A/F)

The relative proportions of the fuel and air in the engine are very important from the standpoint of combustion and the efficiency of the engine. This is expressed either as a ratio of the mass of the fuel to that of the air or vice versa.

In the SI engine the fuel-air ratio practically remains a constant over a wide range of operation. In CI engines at a given speed the air flow does not vary with load; it is the fuel flow that varies directly with load. Therefore, the term fuel-air ratio is generally used instead of air-fuel ratio.

A mixture that contains just enough air for complete combustion of all the fuel in the mixture is called a chemically correct or stoichiometric fuel-air ratio. A mixture having more fuel than that in a chemically correct mixture is termed as rich mixture and a mixture that contains less fuel (or

Performance of IC Engine

excess air) is called a lean mixture. The ratio of actual fuel-air ratio to stoichiometric fuel-air ratio is called equivalence ratio and is denoted by ϕ.

$$\phi = \frac{\text{Actual fuel-air ratio}}{\text{Stoichiometric fuel-air ratio}} \tag{1.19}$$

Accordingly, $\phi = 1$ means stoichiometric (chemically correct) mixture, $\phi < 1$ means lean mixture and $\phi > 1$ means rich mixture.

1.8.12 Calorific Value (CV)

Calorific value of a fuel is the thermal energy released per unit quantity of the fuel when the fuel is burned completely and the products of combustion are cooled back to the initial temperature of the combustible mixture. Other terms used for the calorific value are heating value and heat of combustion.

When the products of combustion are cooled to 25 °C practically all the water vapour resulting from the combustion process is condensed. The heating value so obtained is called the higher calorific value or gross calorific value of the fuel. The lower or net calorific value is the heat released when water vapour in the products of combustion is not condensed and remains in the vapour form.

Performance of IC Engine

1.1 The cubic capacity of a four-stroke over-square spark-ignition engine is 245 cc. The over-square ratio is 1.1. The clearance volume is 27.2 cc. Calculate the bore, stroke and compression ratio of the engine.

Solution

$$\text{Cubic capacity, } V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \frac{d^3}{1.1} = 245$$

$$d^3 = 343$$

$$\text{Bore, } d = \mathbf{7\ cm} \qquad \text{Ans}$$

$$\text{Stroke, } L = \frac{7}{1.1} = \mathbf{6.36\ cm} \qquad \text{Ans}$$

$$\text{Compression ratio, } r = \frac{V_s + V_c}{V_c}$$

$$= \frac{245 + 27.2}{27.2} = \mathbf{10} \qquad \text{Ans}$$

Performance of IC Engine

1.2 The mechanical efficiency of a single-cylinder four-stroke engine is 80%. The frictional power is estimated to be 25 kW. Calculate the indicated power (ip) and brake power (bp) developed by the engine.

Solution

$$\frac{bp}{ip} = 0.8$$

$$ip - bp = 25$$

$$ip - 0.8 \times ip = 25$$

$$ip = \frac{25}{0.2} = \mathbf{125\ kW} \quad \Leftarrow \text{Ans}$$

$$bp = ip - fp = 125 - 25 = \mathbf{100\ kW} \quad \Leftarrow \text{Ans}$$

Performance of IC Engine

1.3 A 42.5 kW engine has a mechanical efficiency of 85%. Find the indicated power and frictional power. If the frictional power is assumed to be constant with load, what will be the mechanical efficiency at 60% of the load?

$$\text{Indicated power, } ip = \frac{bp}{\eta_m} = \frac{42.5}{0.85} = \mathbf{50\ kW} \quad \underleftarrow{\text{Ans}}$$

$$\text{Frictional power, } fp = ip - bp = 50 - 42.5$$

$$= \mathbf{7.5\ kW} \quad \underleftarrow{\text{Ans}}$$

$$\text{Brake power at 60\% load} = 42.5 \times 0.6 = 25.5\ \text{kW}$$

$$\text{Mechanical efficiency } \eta_m = \frac{bp}{bp + fp} = \frac{25.5}{25.5 + 7.5}$$

$$= 0.773 = \mathbf{77.3\%} \quad \underleftarrow{\text{Ans}}$$

Performance of IC Engine

1.5 A four-stroke, four-cylinder diesel engine running at 2000 rpm develops 60 kW. Brake thermal efficiency is 30% and calorific value of fuel (CV) is 42 MJ/kg. Engine has a bore of 120 mm and stroke of 100 mm. Take $\rho_a = 1.15$ kg/m^3, air-fuel ratio = 15:1 and $\eta_m = 0.8$. Calculate (i) fuel consumption (kg/s); (ii) air consumption (m^3/s); (iii) indicated thermal efficiency; (iv) volumetric efficiency; (v) brake mean effective pressure and (vi) mean piston speed

Solution

$$\text{Fuel consumption, } \dot{m}_f = \frac{bp}{\eta_{bth} \times CV} = \frac{60}{0.3 \times 42000}$$

$$= \mathbf{4.76 \times 10^{-3}\ kg/s} \quad \stackrel{\text{Ans}}{\Longleftarrow}$$

$$\text{Air consumption} = \frac{\dot{m}_f}{\rho_a}\frac{A}{F} = \frac{4.76 \times 10^{-3}}{1.15} \times 15$$

$$= \mathbf{62.09 \times 10^{-3}\ m^3/\ s} \quad \stackrel{\text{Ans}}{\Longleftarrow}$$

$$\text{Air flow rate/cylinder} = \frac{62.09 \times 10^{-3}}{4} = 15.52 \times 10^{-3}\ \text{m}^3/\text{s}$$

Performance of IC Engine

$$\text{Indicated power} = \frac{bp}{\eta_m} = \frac{60}{0.8} = 75 \text{ kW}$$

$$\eta_{ith} = \frac{75}{4.76 \times 10^{-3} \times 42000}$$

$$= 0.37515 = \mathbf{37.51\%}$$

Ans ⟸

Volumetric efficiency =

$$\frac{\text{Actual volume flow rate of air}}{\text{Volume flow rate of air corresponding to displacement volume}} \times 100$$

$$\eta_v = \frac{15.52 \times 10^{-3}}{\frac{\pi}{4} \times 0.12^2 \times 0.10 \times \frac{2000}{120}} \times 100$$

$$= \mathbf{82.3\%}$$

Ans ⟸

Performance of IC Engine

$$p_{bm} = \frac{bp}{LAnK}$$

$$= \frac{60}{0.1 \times \frac{\pi}{4} \times 0.12^2 \times \frac{2000}{2 \times 60} \times 4} \times 10^3$$

$$= 7.96 \times 10^5 \text{ N/m}^2 = \mathbf{7.96\ bar} \quad \text{Ans}$$

$$\text{Mean piston speed} = \frac{2 \times 0.1 \times 2000}{60} = 6.67 \text{ m/s} \quad \text{Ans}$$

Performance of IC Engine

1.6 A single-cylinder, four-stroke hydrogen fuelled spark-ignition engine delivers a brake power of 20 kW at 6000 rpm. The air-gas ratio is 8:1 and the calorific value of fuel is 11000 kJ/m^3. The compression ratio is 8:1. If volumetric efficiency is 70%, indicated thermal efficiency is 33% and the mechanical efficiency is 90%, calculate the cubic capacity of the engine.

Solution

$$\text{Energy input} = \frac{bp/\eta_m}{\eta_{ith}} = \frac{20}{0.8 \times 0.33}$$

$$= 75.76 \text{ kJ/s}$$

$$\text{Number of power strokes/s} = \frac{N}{2 \times 60} = \frac{6000}{120} = 50$$

$$\text{Energy input/power stroke} = \frac{75.76}{50} = 1.52 \text{ kJ}$$

$$\text{Actual volume of } H_2 \times CV = 1.52$$

Performance of IC Engine

Actual volume of hydrogen taken in $= \dfrac{1.52 \times 10^6}{11000} = 138.18$ cc

Actual volume of air take in $= \dfrac{A}{F} \times 138.18 = 8 \times 138.18$

$= 1105.44$ cc

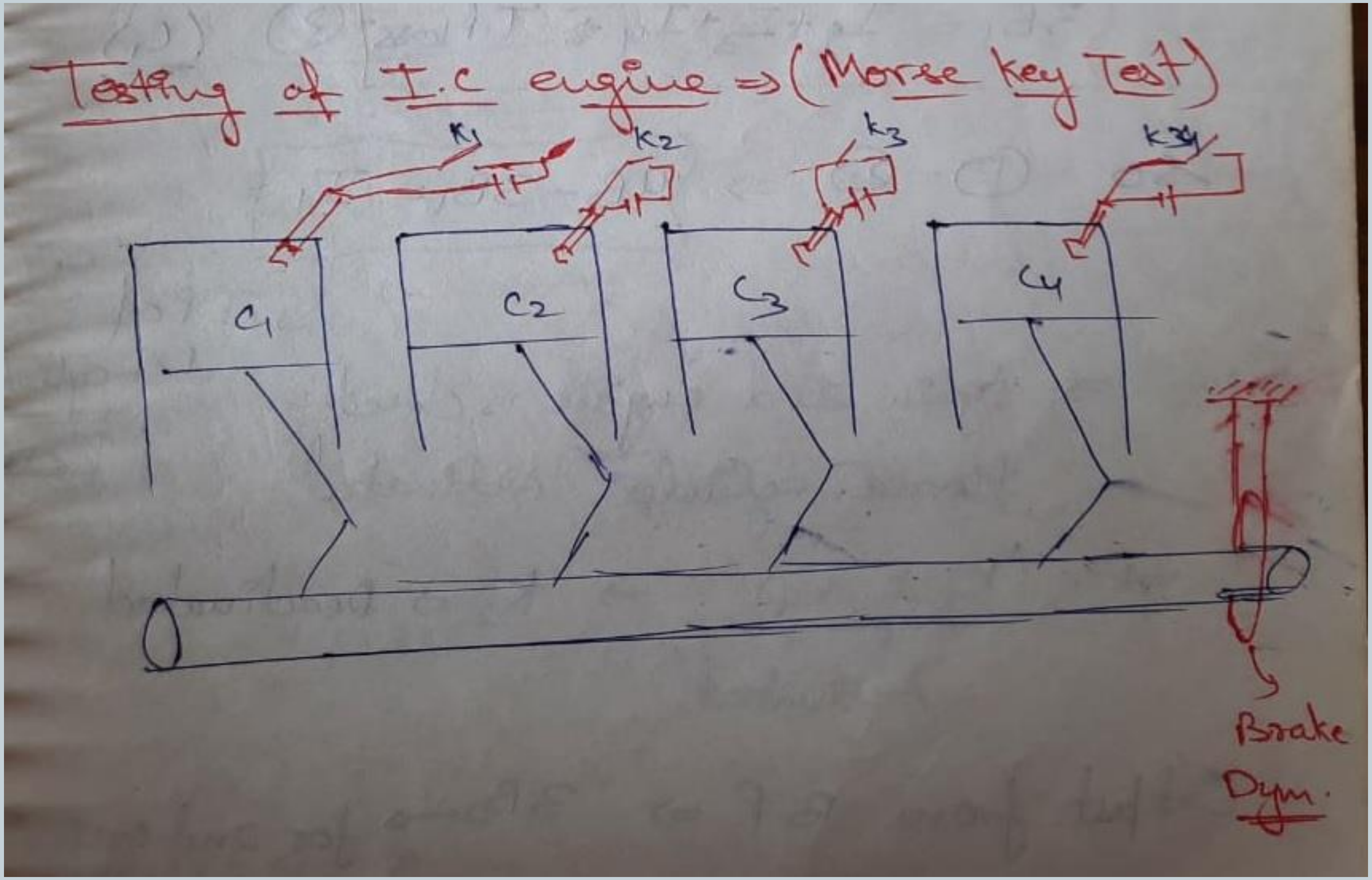
Swept volume, $V_s = \dfrac{\text{Actual volume of air taken in}}{\eta_v}$

$= \dfrac{1105.44}{0.7} = 1579.2$ cc

Cubic capacity of the engine $= V_s \times K = 1579.2 \times 1$

$=$ **1579.2 cc** Ans

Morse Test


Testing of I.C engine => (Morse key Test)
K1
K2
K3
C1
C2
C3
C4
Brake Dyn.

Morse Test continue

Initialy All cylinder working ($K_1 K_2 K_3 K_4$) ← All Activated

Output from B.P ⇒ $4B$

$$4B = I_1 + I_2 + I_3 + I_4 - T.f.\text{loss} \quad \text{— (1)}$$

~~$4B = 4I + 4F$ (1)~~

Secondaly ⇒ ~~All cyli~~ three cylinder working

($K_2 K_3 K_4$) ← active → K_1 → ~~closed~~ Deactivated

Output from ⇒ B.P ⇒ $3B_1$ → for 1st cylinder off (C_1)

$$3B_1 = I_2 + I_3 + I_4 - T.f\,\text{loss} \quad \text{— (2)}$$

Morse Test continue

So (1) − (2) $\Rightarrow$ $4B - 3B_1 = I_1$ $\rightarrow$ I.P of 1st cylinder (C_1)

Then $\Rightarrow$ Again 2nd engine is closed three cylinder Activated.

$\Rightarrow$ $(K_1\ K_3\ K_4)$ $\Rightarrow$ K_2 $\Rightarrow$ Deactivated

$(K_1\ K_3\ K_4)$ → Activated.

Output from B.P $\Rightarrow$ $3B_2$ $\rightarrow$ for 2nd cylinder not working

Morse Test continue

$$3B_2 = I_1 + I_3 + I_4 - T.F_{loss} \quad \text{— (3)}$$

So (1) − (3) ⇒ $I_2 = 4B - 3B_2$

Similarly

for Deactivated Cylinder C3 ⇒ $3B_3 = I_1 + I_2 + I_4 - T.F_{loss}$ — (4)

Deactivated C4 ⇒ $3B_4 = I_1 + I_2 + I_3 - T.F_{loss}$ — (5)

(1) − (3) ⇒ $4B - 3B_3 = I_3$

(1) − (4) ⇒ $4B - 3B_4 = I_4$

Morse Test :→ $\eta_{mech} = \frac{4B}{4I}$ $\{4I = I_1 + I_2 + I_3 + I_4\}$

Directly give

Also I.P. {For single cylinder it will not give I.P}

Morse Test continue

Pb Following Readings are: → For Morse test

	B.P (kW)
All cylinder firing	= 12.5
1 cylinder off	= 9.0
2 " "	= 9.5
3 " "	= 8.8
4 " "	= 9.2

3.5
3
3.7
3.3

I.P = 13.5

$\eta_m = 92.5$

C.V of fuel is ⇒ 42000 kJ

$m_f = 0.07$ kg/min

$\eta_{Ith} = 50\%$ of Air standard η

Morse Test continue

Determine ⇒ (1) cylinder dim., $V_c = 75\ cm^3$

$L = 1.25\,D$

Sol

$B.P = 12.5\ kW$

$I.P = 13.5\ kW$

$$H.A = \frac{0.07 \times 42000}{60} = 49\ kW$$

$$\eta_{Ith} = \frac{13.5}{49} = 27.55\%$$

$$\eta_{Ith} = .5\ \eta_{Air\ stand.}$$

$$\eta_{Air\ standard} = 55.1020\%$$

Morse Test continue

$$55.102 \times \frac{1}{100} = 1 - \left(\frac{1}{r}\right)^{\gamma - 1}$$

$$r = 7.4034$$

$$r = \frac{V_c + V_s}{V_c} = 7.4034$$

$$V_s = 480.25 \text{ cm}^3$$

so

$$\frac{\pi}{4} \times D^2 \times 1.25D = 480.25$$

$$D = 7.879 \text{ cm}$$

$$L = 9.849 \text{ cm}$$

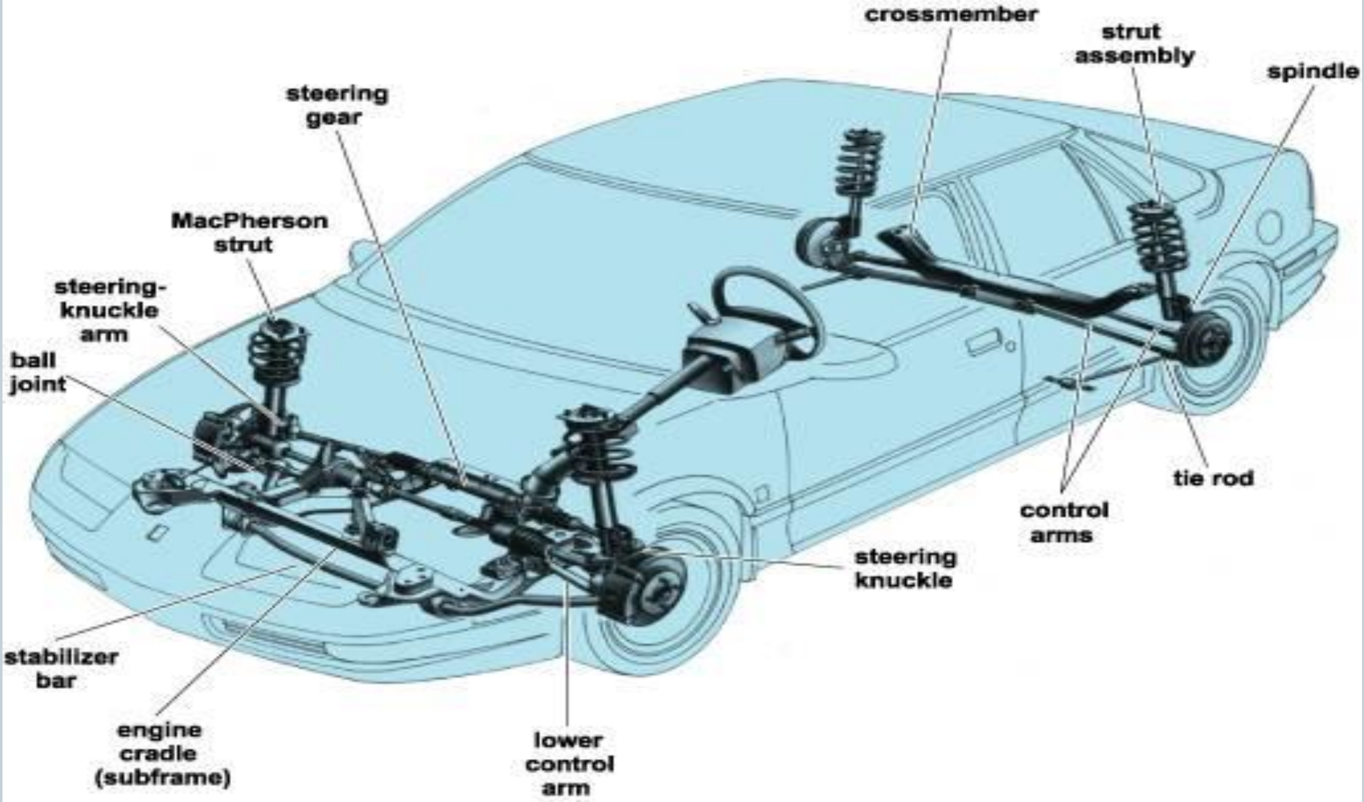
Chapter-4
Suspension System

Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels

- Serve a dual purpose – contributing to the car's handling and braking.
- Protects the vehicle itself and any cargo or luggage from damage and wear

Suspension System

SUSPENSION SYSTEM – LAY OUT



Suspension System

Different suspension systems

- Conventional suspension system
- Independent suspension system
- Air suspension system
- Hydro elastic suspension system

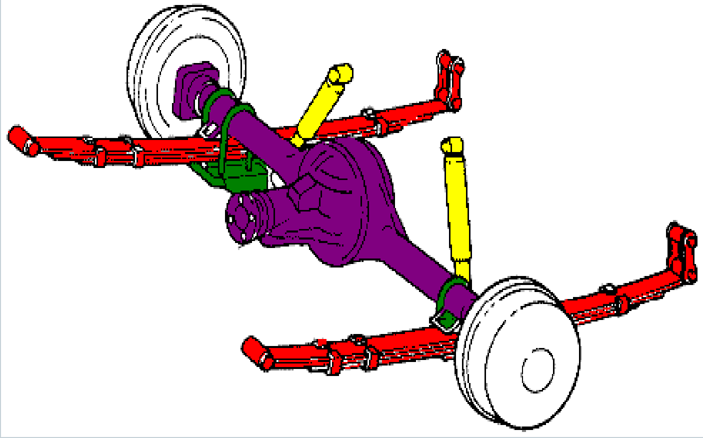
Suspension System

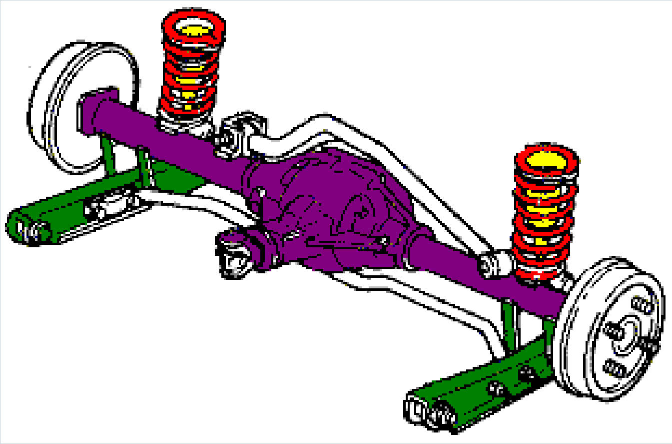
Conventional suspension system

- Two wheels are mounted on either side of the rigid axle
- When one wheel encounters the bump, both the wheel do not execute parallel up and down motion
- So it gives rise to gyroscopic effect and wheel wobble
- Rear driving wheels mounted on live axle suspended by laminated leaf springs and shock absorbers

Suspension System

Conventional suspension system





Suspension System

Independent suspension system

- Both the front and the rear wheels are utilized
- Design incorporated in the front wheels
- One wheel goes down, the other wheel does not have much effect

Basic classification of the design

1. **MacPherson Strut**
2. **Double Wishbone**
3. **Multilink**

Suspension System

MACPHERSON STRUT

- The most widely used front suspension system in cars
- comprises of strut-type spring and shock absorber combo, which pivots on a ball joint on the single lower arm.
- The steering gear is either connected directly to the lower shock absorber housing or to an arm from the front or back of the spindle (in this case
- When you steer, it physically twists the strut and shock absorber housing (and consequently the spring) to turn the wheel

DOUBLE WISHBONE SUSPENSION

Type of *double-A* or *double wishbone* suspension

Wheel spindles are supported by an upper and lower 'A' shaped arm.

The lower arm carries most of the load. If you look head-on at this type of system, a parallelogram system allows the spindles to travel vertically up and down. This side-to-side motion is known as scrub

Type of double-A arm suspension although the lower arm in these systems can sometimes be replaced with a single solid arm (as in my picture). The spring/shock combo is moved from between the arms to above the upper arm. This transfers the load-bearing capability of the suspension almost entirely to the upper arm and the spring mounts.

The lower arm in this instance becomes a control arm.

Suspension System

Multi-link suspension

- It's currently being used in the Audi A8 and A4 cars.
- The basic principle of it is the same, but instead of solid upper and lower wishbones, each 'arm' of the wishbone is a separate item.
- These are joined at the top and bottom of the spindle, thus forming the wishbone shape.
- The super-weird thing about this is that as the spindle turns for steering, it alters the suspension's geometry by torquing all four suspension arms.
- Spring is separate from the shock absorber.

Suspension System

Independent front Suspension System

Advantages

- Bigger deflection of front wheels, no reaction on steering
- Greater distance for resisting rolling action
- Front axle (small-stub) improves road holding tendency of tires.
- Minimum vibrations

Disadvantages

- Better shock absorber required.
- Expensive
- Tyre wear increases due to the transmission of torque

Suspension System

Independent rear suspension

Advantages

- Lesser unsprung weight – improves ride and reduces tyre wear.
- Increased passenger space
- Rear wheels remain stable.

Disadvantages

- Increased cost
- Complicated design
- Steering action is not proper

Suspension System

Traverse suspension system

- Normally found on the rear suspension
- Combines independent double wishbone suspension with a leaf spring.
- It involves one leaf spring mounted *across* the vehicle, connected at each end to the lower wishbone.
- The center of the spring is connected to the front subframe in the middle of the car.
- There are still two shock absorbers, mounted one to each side on the lower wishbones.

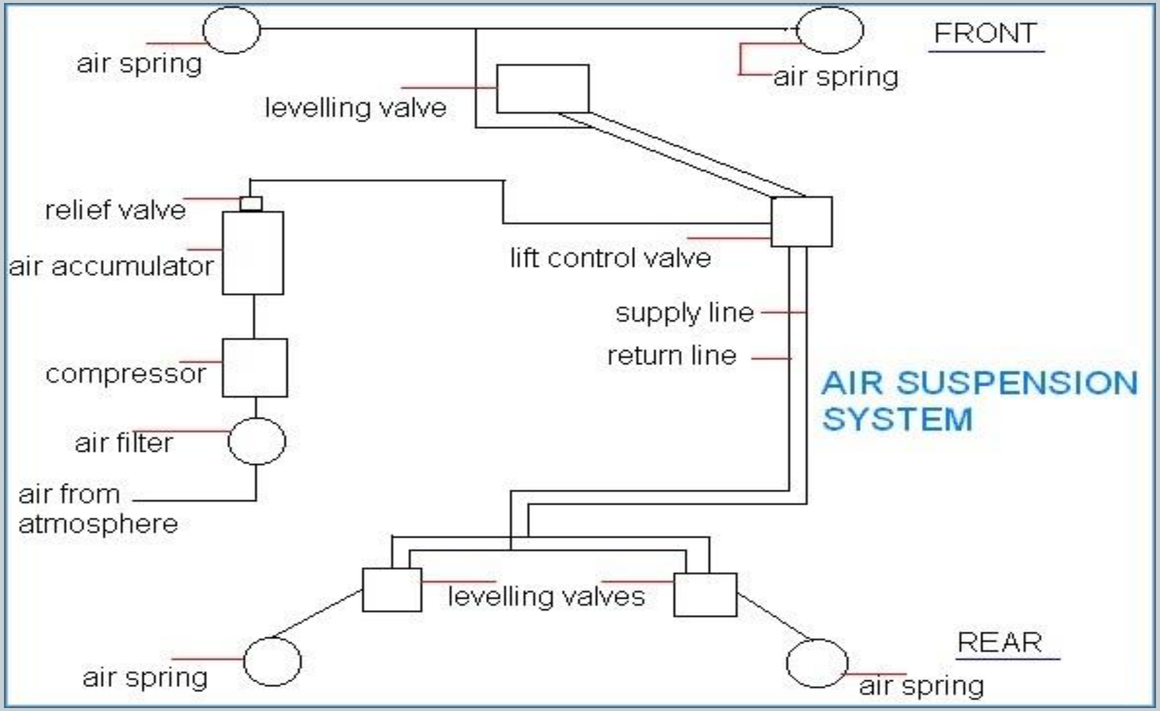
Suspension System

Air suspension

- Comprises of the compressor, supplying air to the air tank
- Pressure maintained – 5.6 to 7 kg/sq.m
- Air bags – on each wheel
- As load is applied, airbags are compressed, actuating the leveling valve.
- Air from the tank fills the compressed air bag & hence raises the level of the frame.
- Air from the airbag gets released as the load on the chassis decreases.

Suspension System

- Air suspension layout



Suspension System

Advantages of air suspension

- Comprises of compressor , suppling air to air tank
- Pressure maintained – 5.6 to 7 kg/sq.m
- Air bags – on each wheel
- As load applied , air bags compressed actuating the levelling valve .
- Air from the tank fills the compressrd air bag & hence raise the level of the frame.
- Air from air bag gets released as load on chassis decreases .

Suspension System

Common Air Suspension Problems

Air bag or air strut failure

- Due to old age, or moisture within the air system that damages them from the inside.

Compressor failure

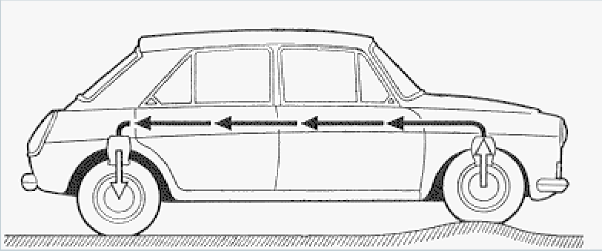
- Primarily due to leaking air springs or air struts**.** Compressor burnout may also be caused by moisture from within the air system coming into contact with its electronic parts.

Dryer failure

- which functions to remove moisture from the air system eventually becomes saturated and unable to perform that function

Suspension System

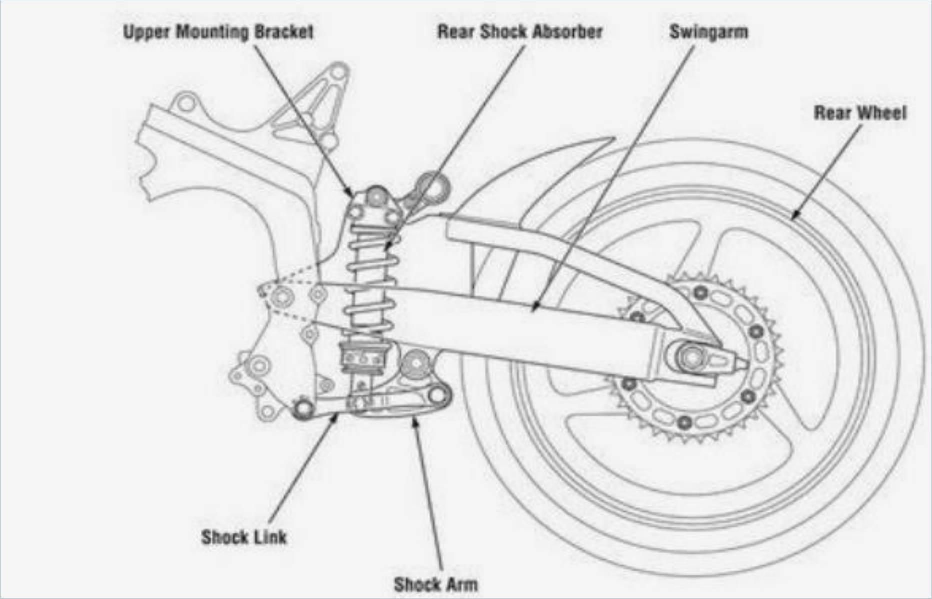
Hydrolastic Suspension



- A system where the front and rear suspension systems were connected together in order to better level the car when driving.
- The front and rear suspension units have Hydrolastic displacers, one per side.
- These are interconnected by a small bore pipe. Each displacer incorporates a rubber spring
- Damping of the system is achieved by rubber valves.

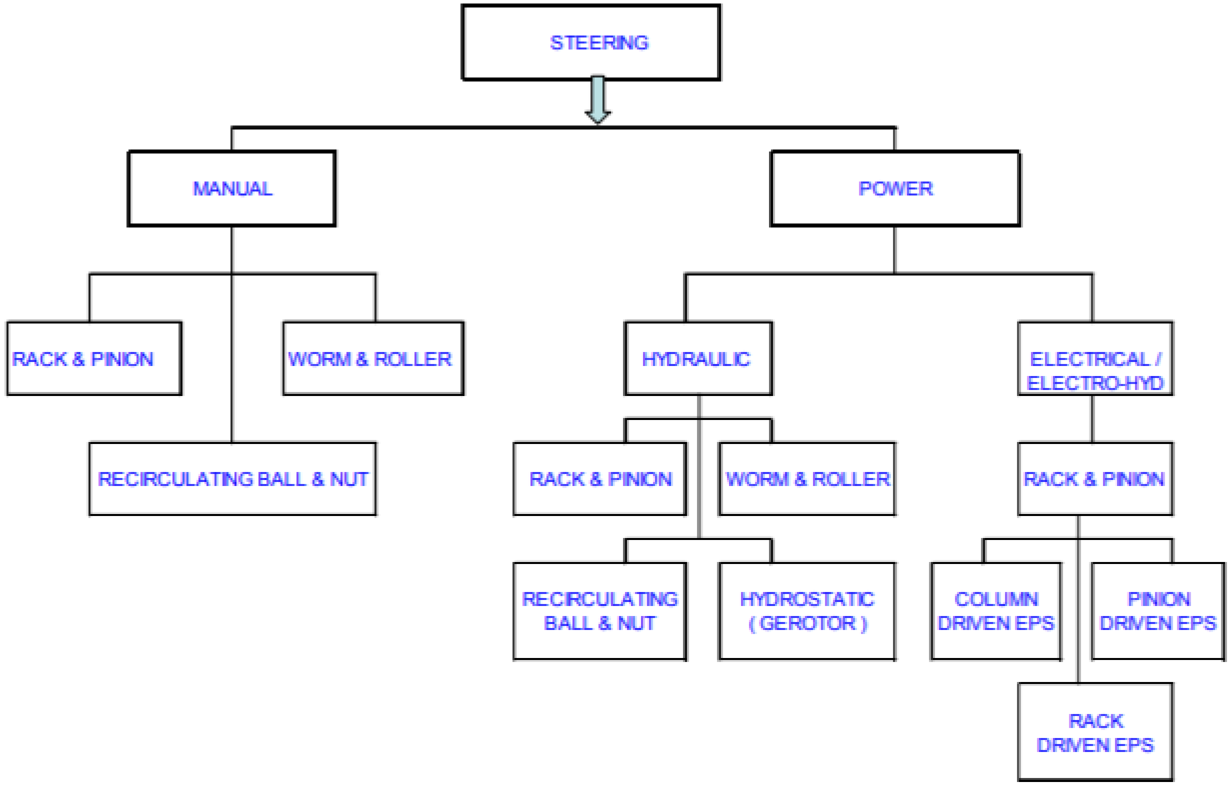
Suspension System

Motorcycle suspension system



Chapter-5
Steering System

Steering systems/mechanisms in use



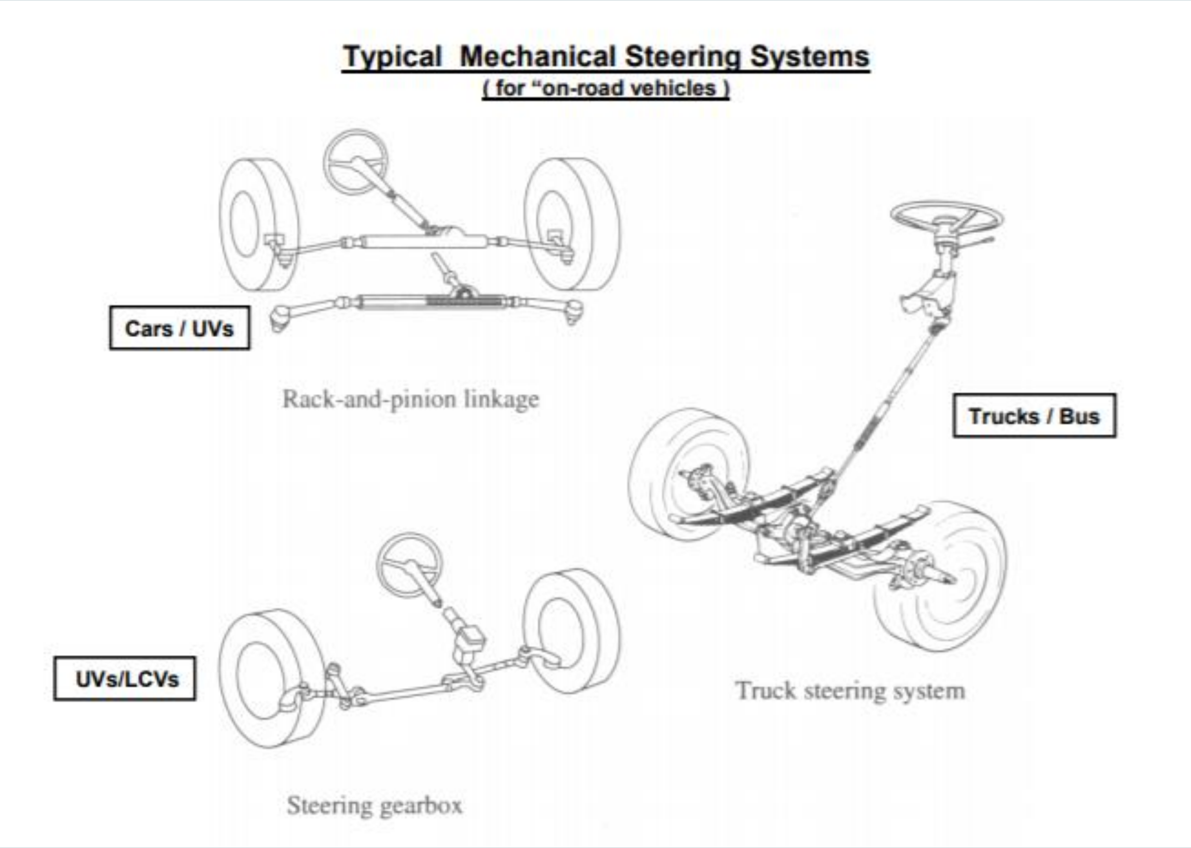
Steering System

Steering systems/mechanisms in use

SL. NO	STEERING MECHANISMS IN USE	STEERING SYSTEM				STEERING RATIO	
		MANUAL	POWER-ASSISSTED			CONSTANT	VARIABLE
			Hydraulic	Electro-hyd	Electric		
1	SCREW & NUT	✓	✓	X	X	✓	✓
2	CAM & LEVER	✓	✓	X	X	✓	✓
3	WORM & ROLLER	✓	✓	X	X	✓	X
4	RECIRCULATING BALL SCREW & NUT	✓	✓	?	?	✓	✓
5	RACK & PINION	✓	✓	✓	✓	✓	✓
6	GEROTOR	✓	✓	✓	X	✓	X

Steering System

Manual Steering System



Steering System

NEED FOR POWER STEERING

The need to achieve the greatest possible road safety under :

INCREASING TRAFFIC DENSITY

Steering System

NEED FOR POWER STEERING

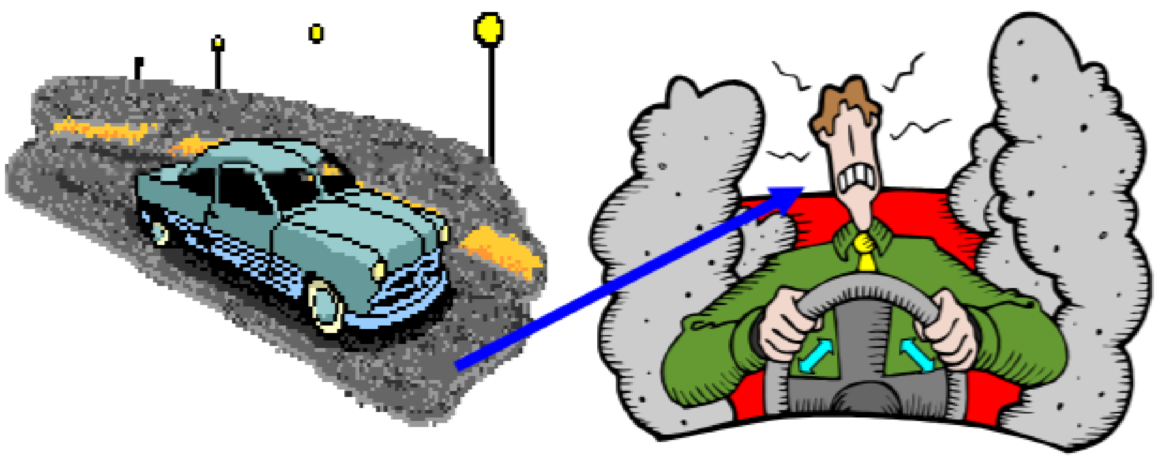
The need to achieve the greatest possible road safety under :

HIGH AXLE LOADS

Steering System

NEED FOR POWER STEERING

The need to achieve the greatest possible road safety under :



POOR ROAD CONDITIONS

Steering System

NEED FOR POWER STEERING

All of the above situations force the driver to operate the vehicle at slow speeds ,increasing steering effort causing FATIGUE TO DRIVERS.

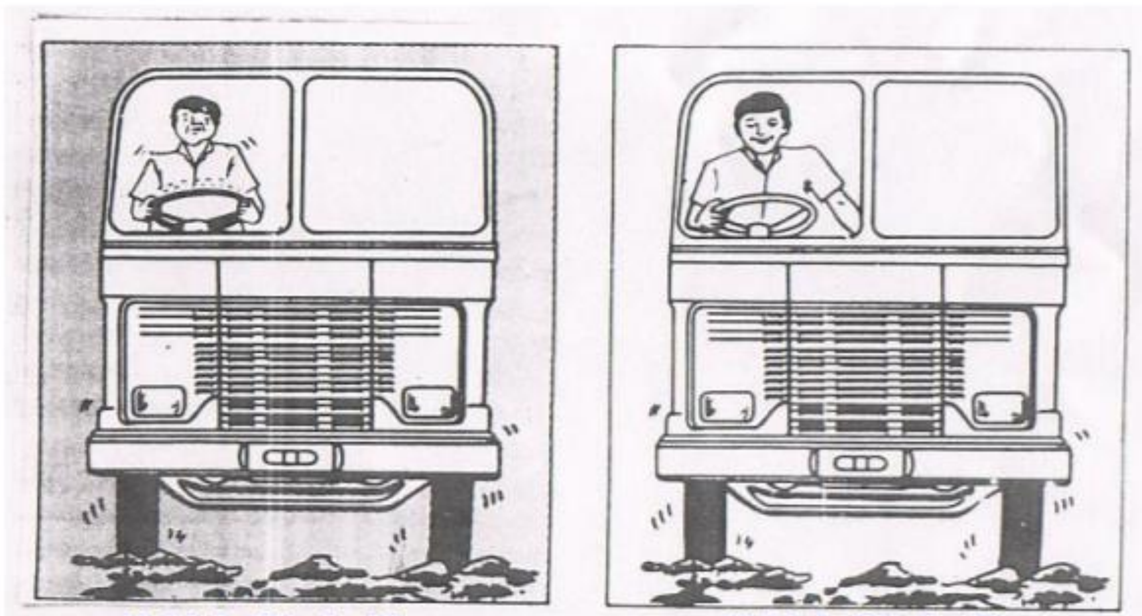
Judgment of a fatigued driver will be poor.

Poor judgment in driving means increased potential for accidents.

LED TO THE DEVELOPMENT OF POWER STEERING

Steering System

BENEFITS OF POWER STEERING



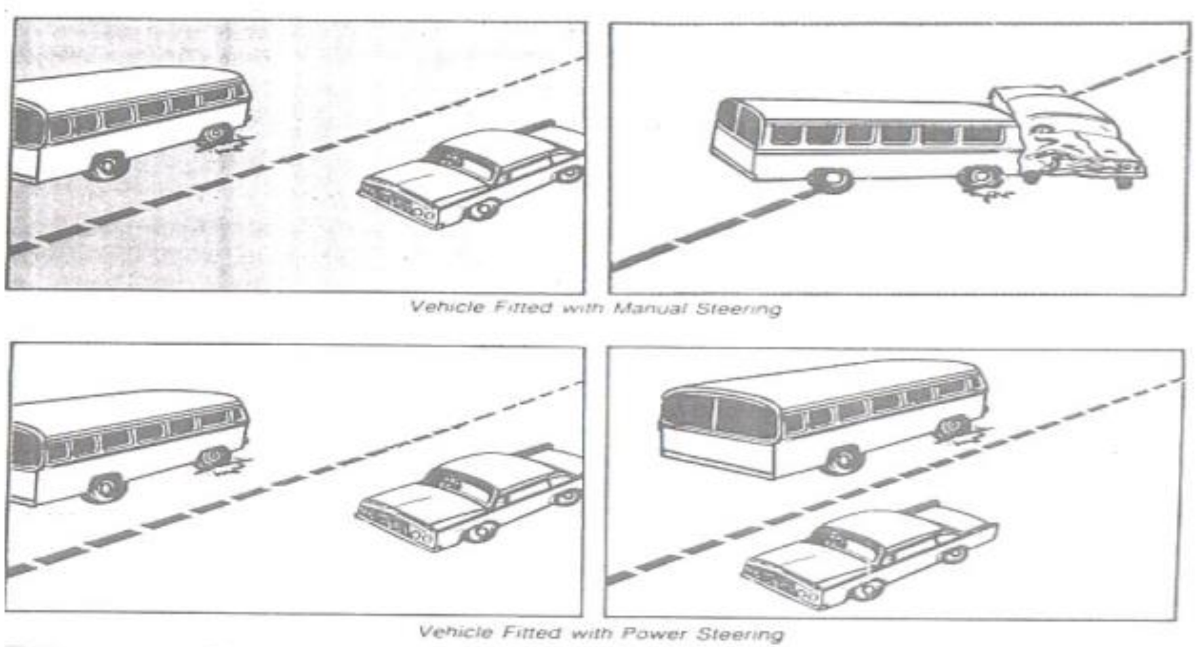
Vehicle fitted with Manual Steering

Vehicle fitted with Power Steering

ABSORBS ROAD SHOCKS

Steering System

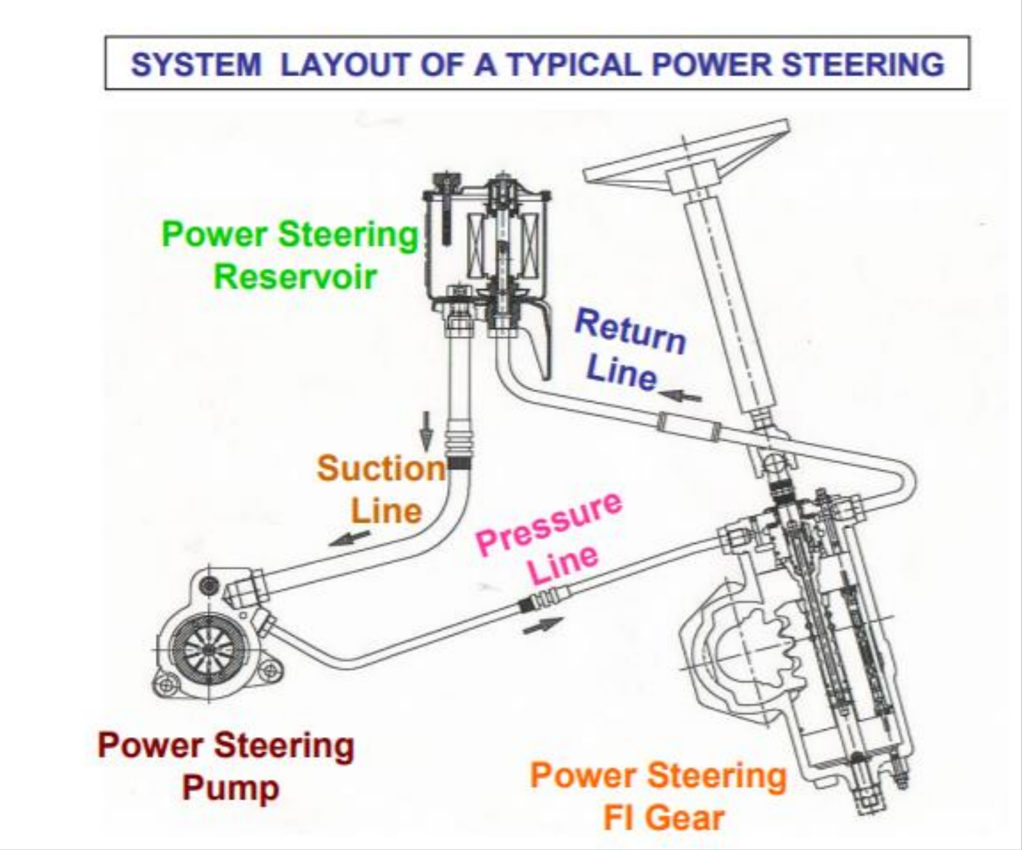
BENEFITS OF POWER STEERING



GREATER SAFETY AND CONTROLLABILITY UNDER CRITICAL SITUATIONS

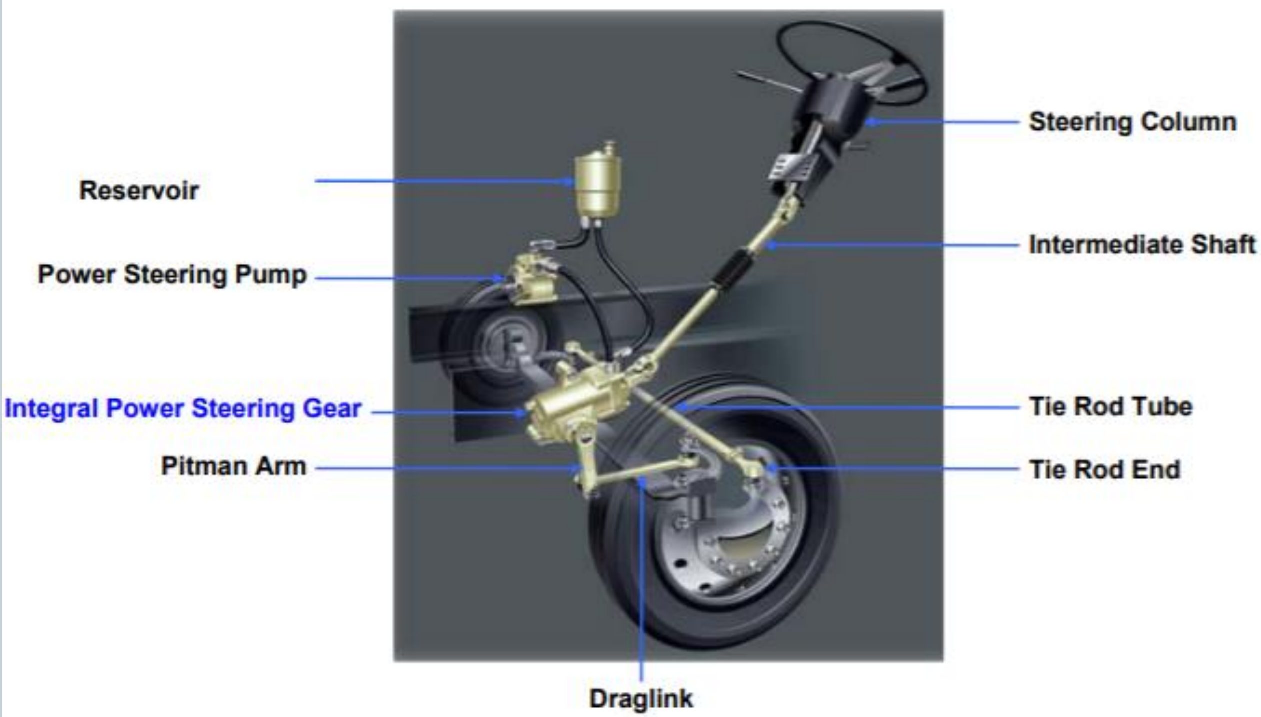
Steering System

Hydraulic Power Steering System



Steering System

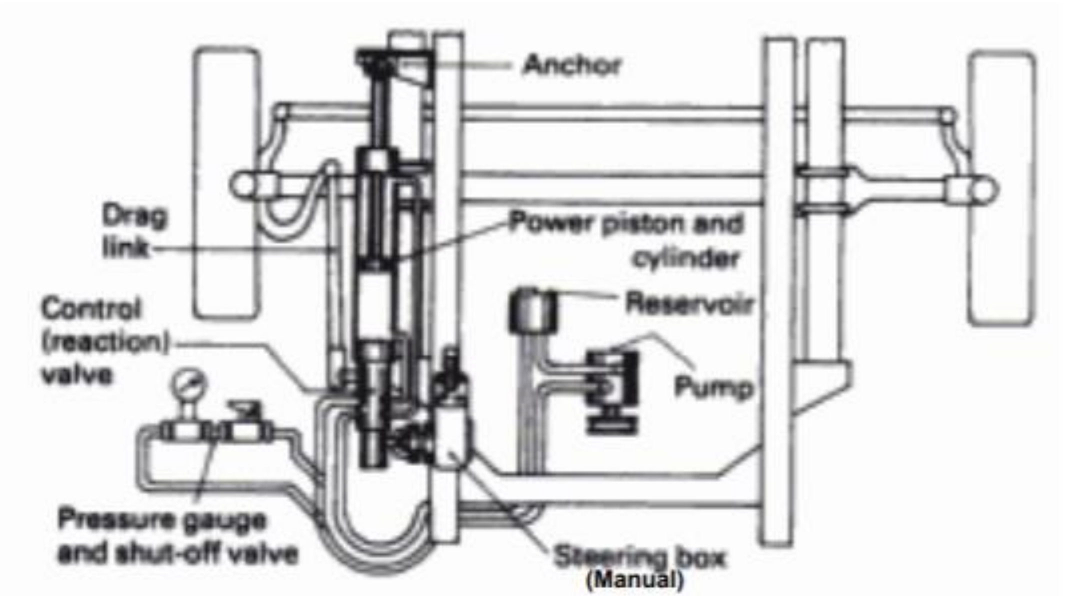
Typical Box-type Power Steering System for CVs
(Tie rod behind the axle)



Integral (Box type) Power Steering System

Steering System

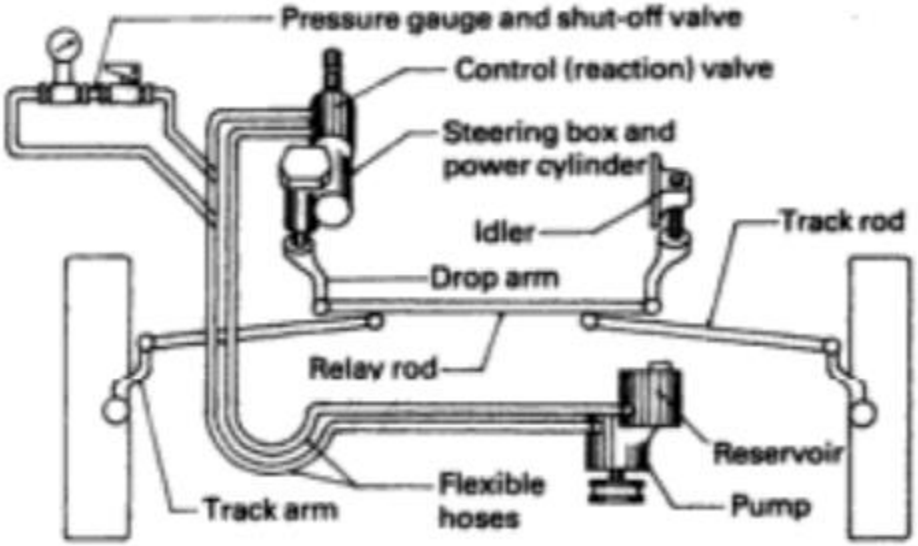
Typical Cylinder-type Power Steering System for CVs
(Tie rod behind the axle)



Cylinder type Power Steering System

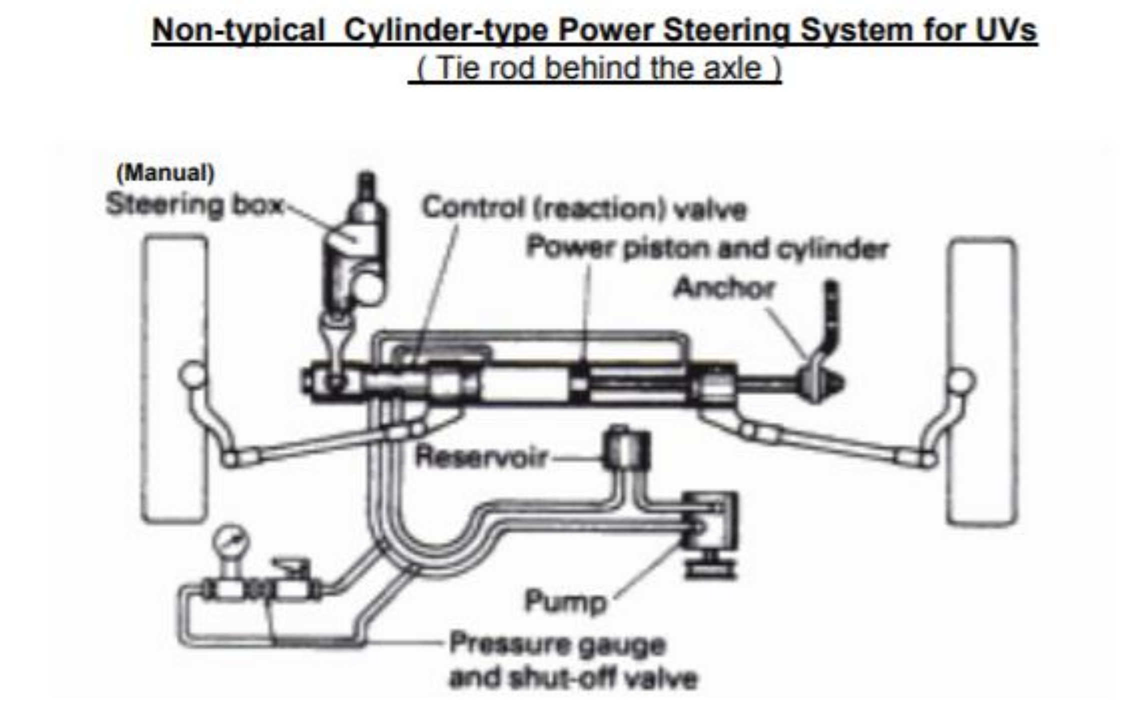
Steering System

Typical Box-type Power Steering System for UVs
(Tie rod behind the axle)



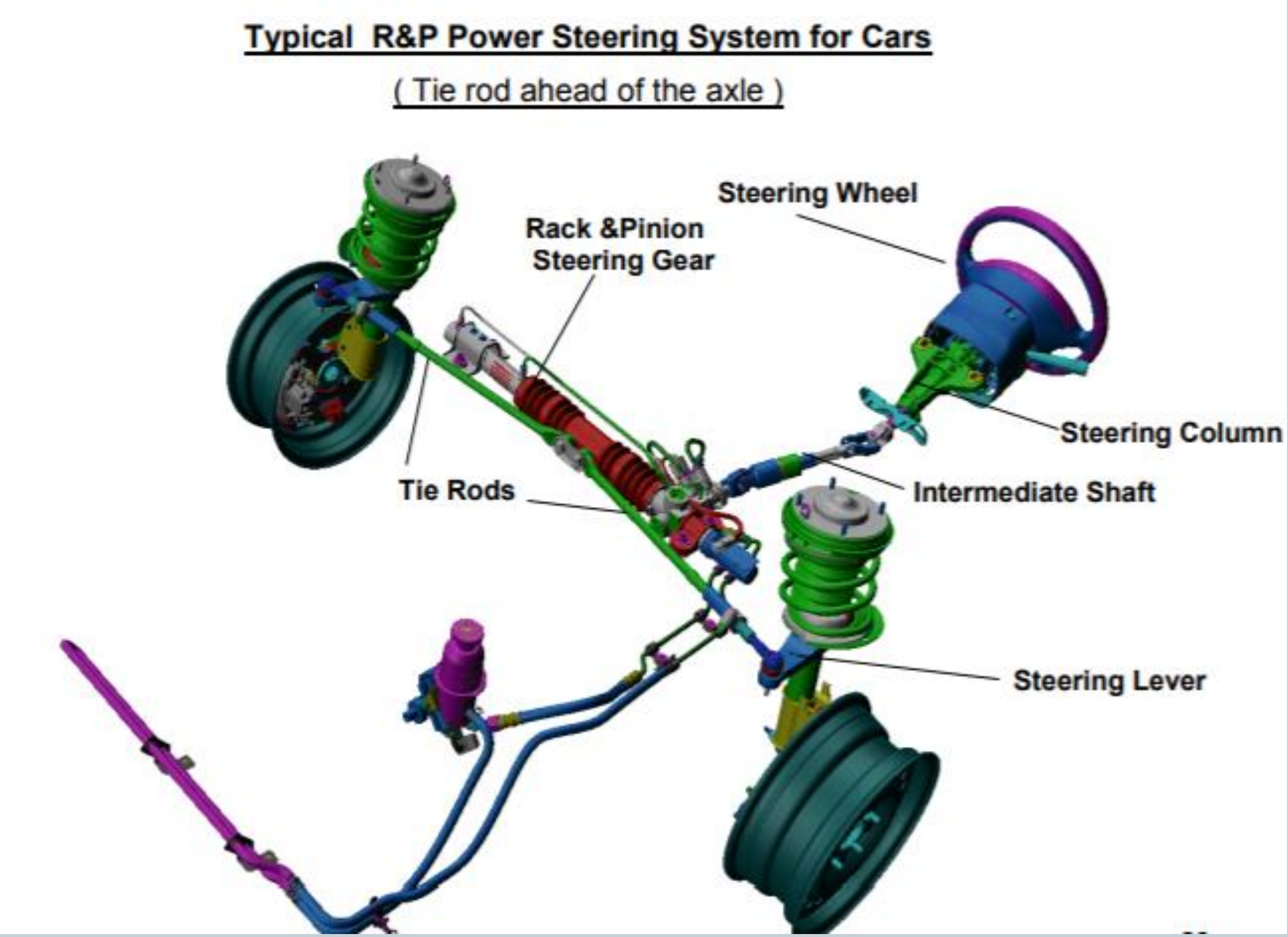
Integral (Box type) Power Steering System

Steering System



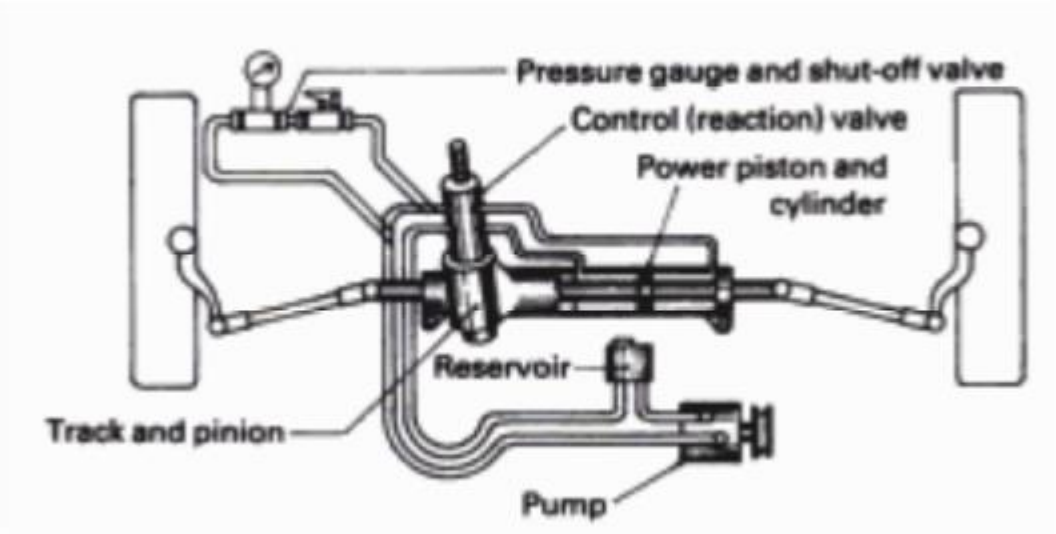
Cylinder type Power Steering System

Steering System



Steering System

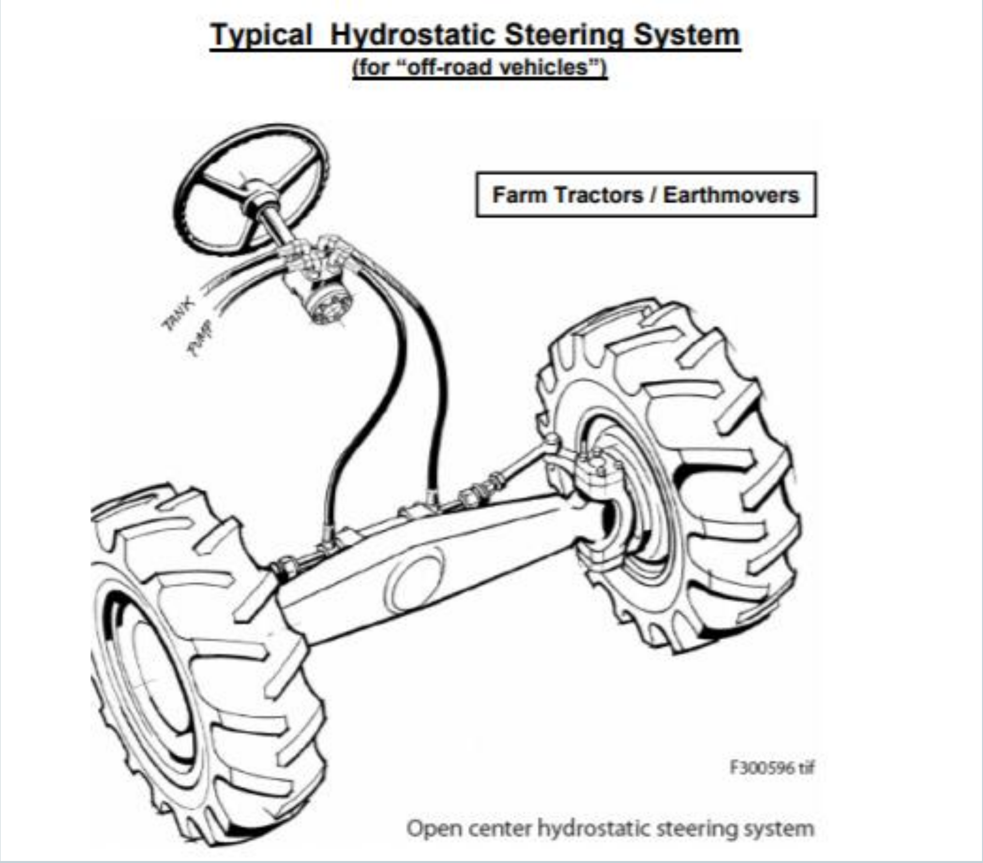
Typical R&P type Power Steering System for Cars / UVs



Integral Rack & Pinion type Power Steering System

Steering System

Hydrostatic Steering System



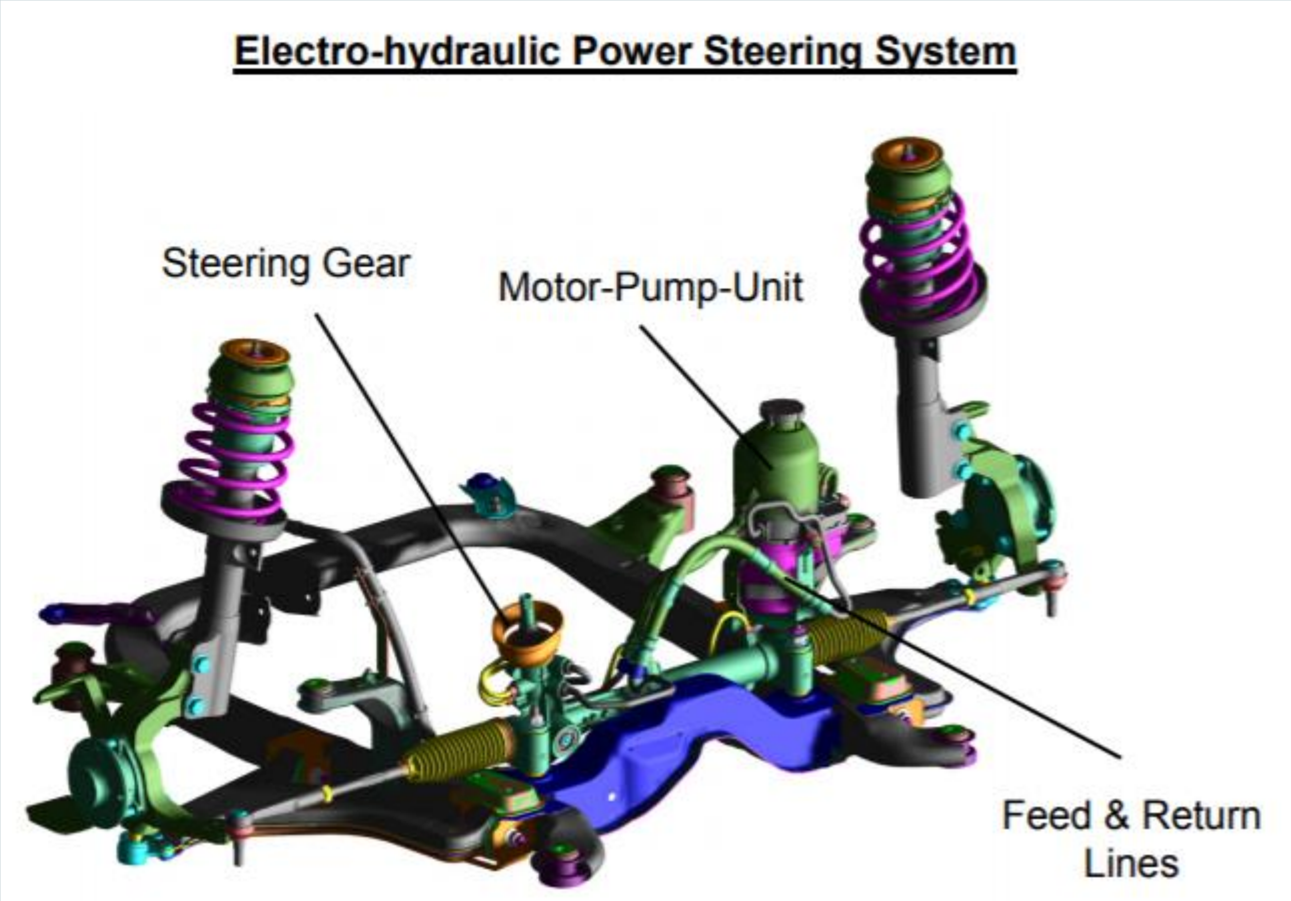
Open center hydrostatic steering system

Steering System

Need for Electric-Hydraulic/Electric Power Steering System

- Fuel Efficiency
- Emission control over engine idle
- Control flexibility through S/W change instead of H/W change
- Integration with other electronic controls on vehicles e.g., ABS, TCS, ESP, etc.

Steering System



Steering System

EHPS Benefits

- **Vehicle Performance / Safety**
  - Steering Feel Tuning i.e. Vehicle and/or Driver Setting
- **Energy Saving**
  - Reduced Fuel Consumption (1 to 3 % Reduction)
  - High System Efficiency
  - Flow on demand and according to Vehicle Speed (speed-pro feel)
  - Low energy consumption, in idle less than 50 Watt
  - Engine independent operation (Engine Shut Off)
- **Future Application Criteria**
  - Interaction with other Chassis/Vehicle Control and Driver Assist Systems
  - Migration of EPHS-technology into EHS- and SBW-Applications
  - MPU-Utilization beyond Steering Applications (e.g. Active and Semi active Chassis, Braking, Power Train (Automated Clutches and Transmissions)

Steering System

Chapter 6
Braking System

INTRODUCTION:- Brakes are an important safety system in all transport vehicles it may be defined as the force which stops any motion brakes are applied to slow down or stop the motion of vehicles. There are many types of brakes as hand brakes, mechanical brakes, hydraulic brakes vacuum servo-assisted hydraulic brakes, and air brakes. Now a day’s, hydraulic and power brakes are mostly used in automobile

Braking System

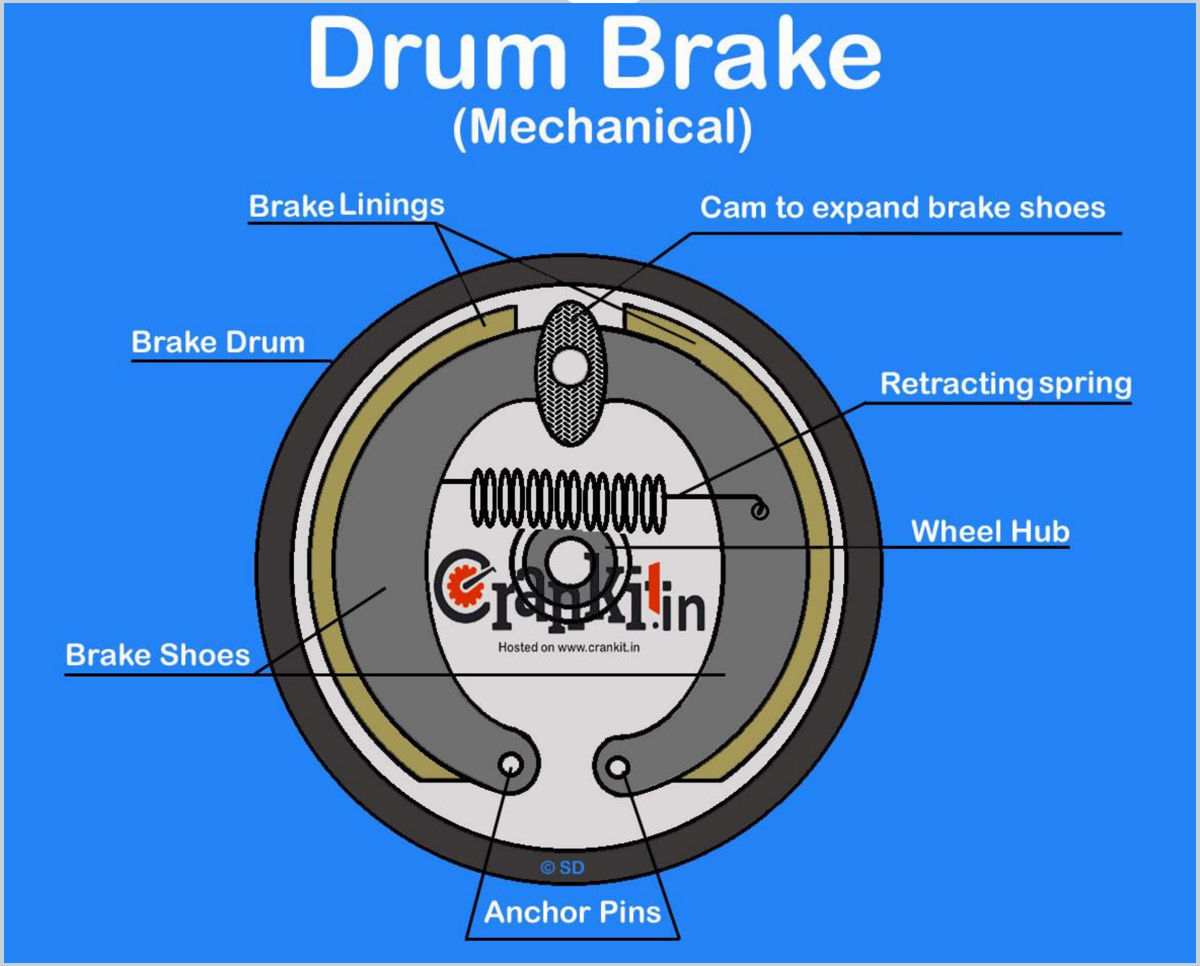
Construction and operation of Mechanical brake system:

- A fixed brake plate attached to the axle housing. A fulcrum is this fixed plate at the bottom. Two brake shoes are fixed to it these shoes are lined on the outer side asbestos or fiber material. A revolving cam is fixed to the top of the brake plate when the cam rotates these two brake shoes expand. A spring connects both the brake shoes and brings them closer. The cam is shown linked by mean of camshaft & a lever. The lever is operated with rod by mean of a pedal. When the pedal is pressed, the cam rotates by slight amount because of the links. This pushes the ends of the brake shoes outward. These brake shoes press against the inner portion of the brake drum thus the rotating wheel is fully stopped. When the brake pedal is released, the spring brings both shoes closer. The pressure on the inner portion of the brake drum is removed. The wheel is thus relieved of the grip of the brake shoes. This is how a mechanical brake is operates.

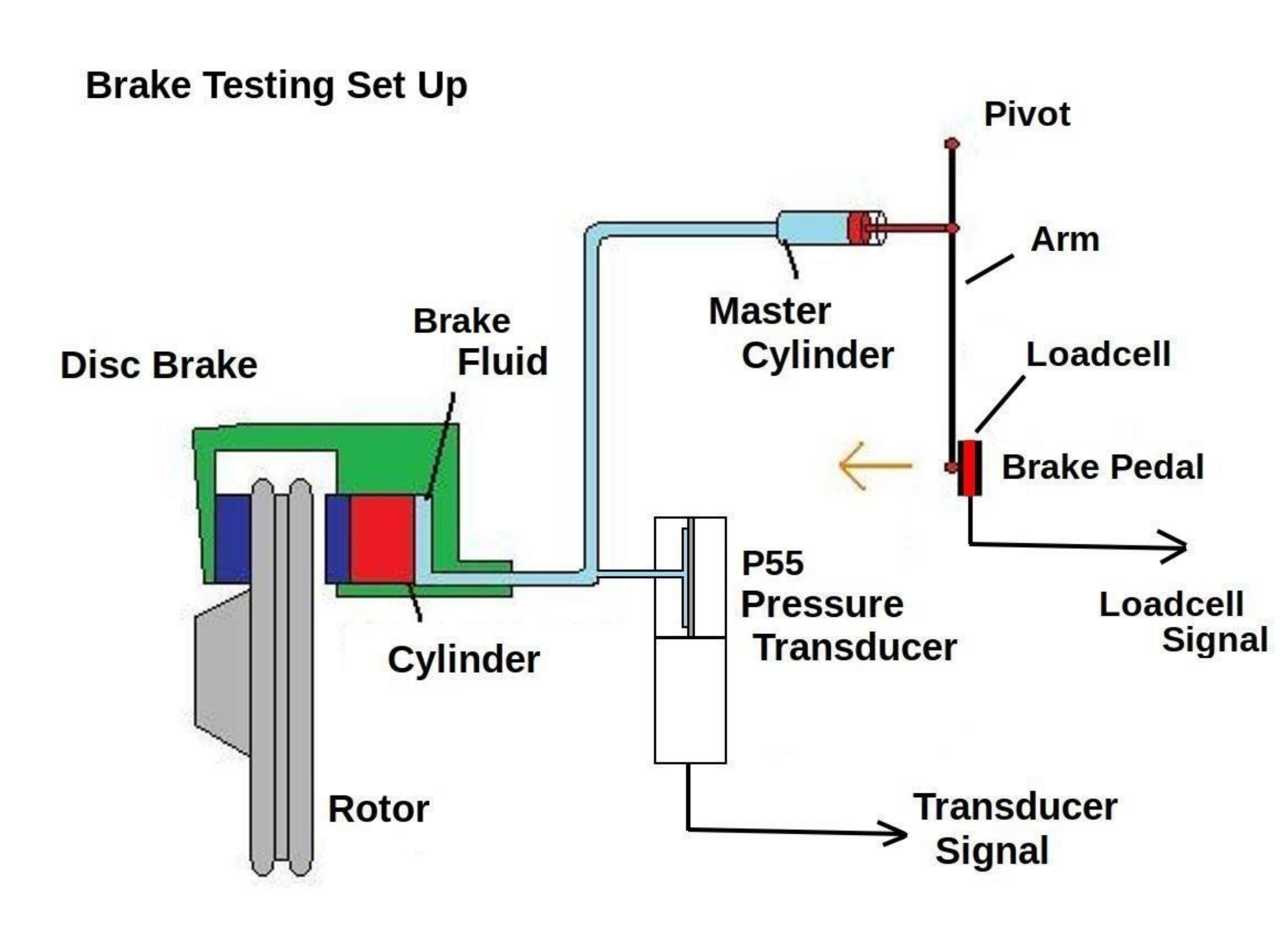
Braking System

- There is one fulcrum for each brake shoe. The mechanical brake linked to all the four wheel of the vehicle by means of proper links. When the pedal is operated the cam on all four wheels is simultaneously rotated. Now the brake shoes on all the four wheels are also in operation. These simultaneously grip the brake drum in all four wheels. When the brake pedal is released, the springs in these brake shoes bring the brake shoes closer the grip on the inner portion of the brake drum is thus relieved. The wheels are now free to rotate.

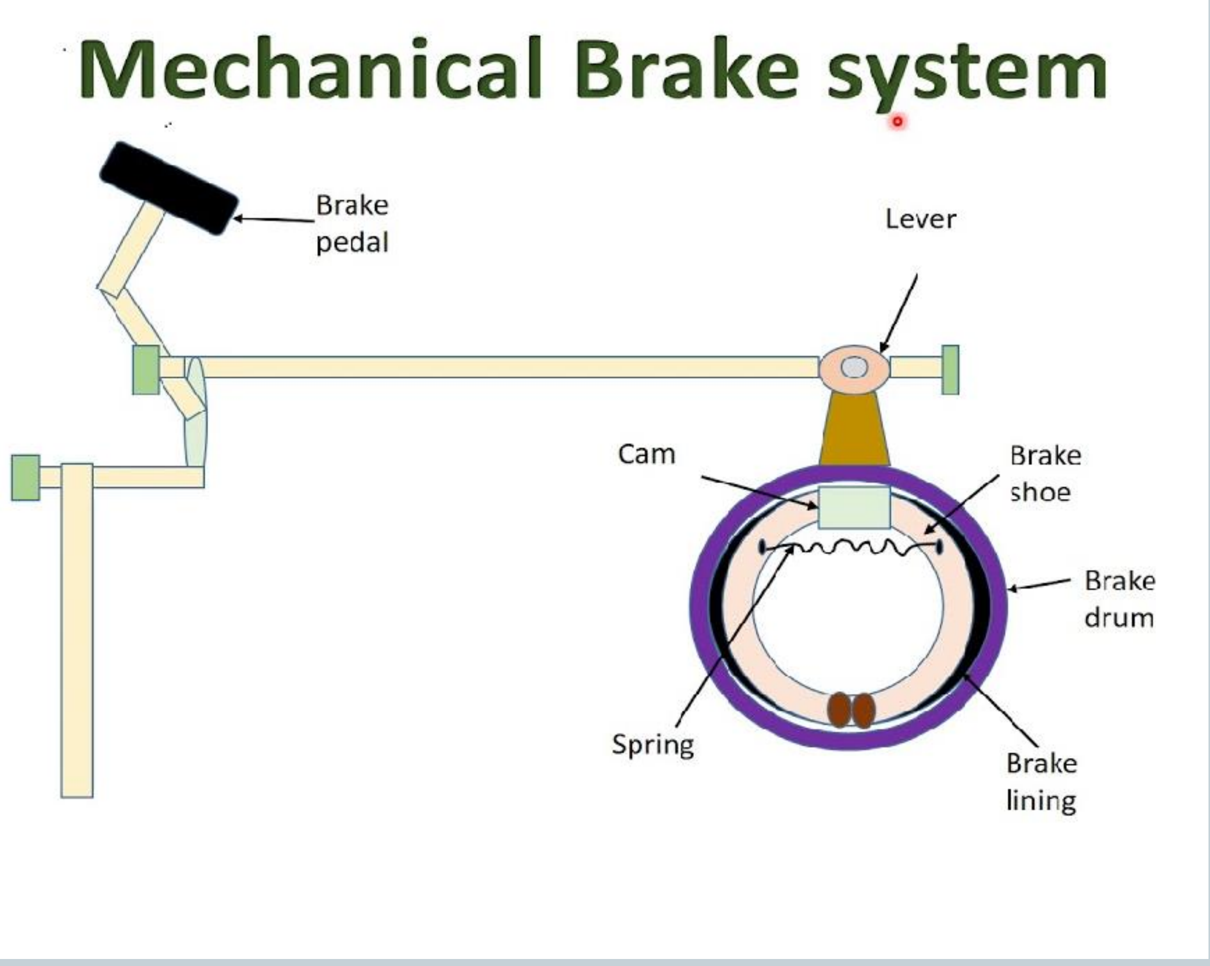
Braking System



Braking System



Braking System



Braking System

Construction and operation of Hydraulic brake system:-

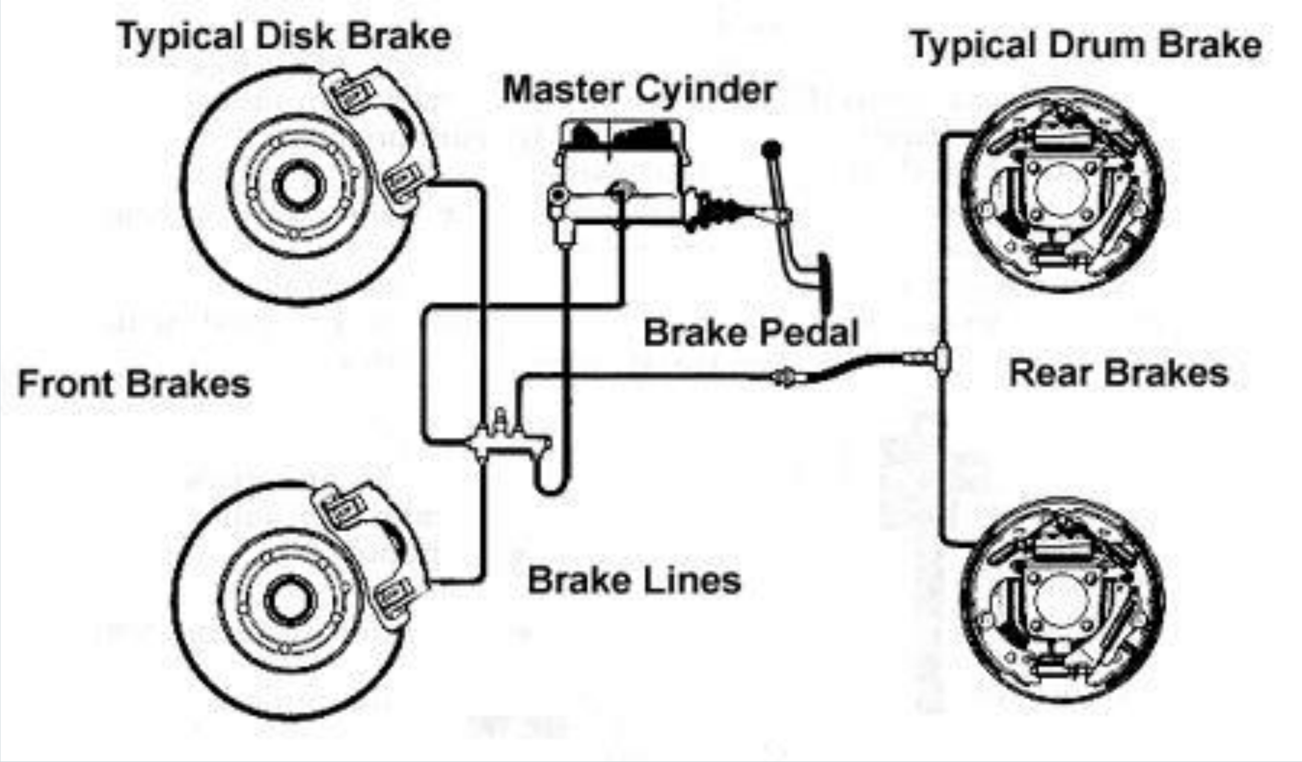
- In the hydraulic brake system five cylinders filled with a liquid. The cross-section of each cylinder is 1 cm sq. A certain force say 10 kg is applied at the central main cylinder. The liquid in the entire cylinder supports these weights. This shows that the pressure at the central main cylinder is the same as that in the other entire four cylinders. This is the principle of hydraulic brake system.
- In hydraulic brake system there is one master cylinder and four-wheel cylinders. Every wheel cylinder contains two pistons, which move outward. The hydraulic fluid flows from the master cylinder to the four-wheel cylinder with the help of suitable pipes.

Braking System

- Springs are used to hold the brake shoes on all four wheels. When the brake pedal is pressed the piston in the mater cylinder forces the liquid out of the cylinder. This liquid presses the two pistons in the wheel cylinder outward. These two pistons push the brake shoes outward. The brake shoes in turn press against the brake drums. The wheels are thus stopped.
- When the brake pedal is released, the master cylinder is pushed backward. This is done by a spring fitted in the master cylinder. The springs of the brake shoes bring the shoe closer. At this time the two pistons in the wheel cylinder also comes closer. The liquid in the wheel cylinder pushed outwards through the pipes. It returns through the pipes to the master cylinder. This is how the hydraulic system of the four wheels operates.

Braking System

Hydraulic Braking System



Chapter7
Transmission System

The internal combustion engine generates power which is transmitted to the road wheels. The output from engine is available in the form of rotation of crankshaft. This rotary motion is transmitted to the road wheels. The friction between road and the surface of the wheel makes possible the movement of automobile. Transmission system performs this function. The transmission system consists of a number of components. These components work together to transmit the rotary motion at the crankshaft smoothly and efficiently to the road wheels.

Sudden change of state, from rest to motion or vice versa is not desirable. It may be uncomfortable, or even injurious, to the occupants of the automobile. Therefore, the rotary motion of crankshaft should be transmitted gradually and not suddenly. Another aspect of transmission is that the motion from the crankshaft should not be transmitted as soon as the engine starts. It is not desirable that as soon as the engine starts the vehicle begins moving. The motion is required to be transmitted only 'when desired'.

The rotary motion of the crankshaft gives rise to torque and transmission of this torque to road wheels give rise to a propulsive force or tractive effort causing the movement of wheels on the road. When starting from rest large tractive effort is needed. The engine produces almost the same torque. This torque has to be enhanced so that enough tractive effort is produced. This necessitates the introduction of 'leverage' between the engine and the road wheels.

A variation in the leverage is essential because if the same leverage is used for climbing as well as moving on the level road, the maximum possible speed would be unduly low. A large leverage implies a large reduction in speed between the engine and the wheels and at quite moderate road speeds the engine speed would be very high. But at high engine speeds the engine torque falls off so that tractive effort available would be less thereby reducing the road speed.

Transmission System

In majority of automobiles, the engines are fitted in the front portion on the frame of the carriage unit. Usually the motion is transmitted to the road wheels on the rear side. The distance between the two is quite considerable. The motion is required to be transmitted through this distance. Also, the rear axle is attached to the frame through springs. Due to uneven surface of the road the axle moves up and down and the springs flex. The relative positions of the engine and the axle changes and transmission system should be capable of taking it up.

The transmission system, therefore, should fulfill the following requirements:

1. Enable the engine to keep disconnected from the road wheels. These should be connected only 'when desired'.
2. Enable the engine, when running, to be connected smoothly and gradually without jerk-to the road wheels.
3. Enable the leverage between the engine and the road wheels. This leverage should be variable to cope with the different conditions such as starting from the rest, moving at uniform speed or climbing a hill.
4. Enable the reduction in the engine speed.
5. Turn the drive through 90 degrees.
6. It should enable the running of inner and outer road wheels at different speeds when the vehicle moves on a curved path.
7. It should provide the relative motion between engine and the road wheels when they move up and down due to uneven road surface.

Components of the Transmission System

The transmission system consists of the following components:

(*a*) Clutch

(*b*) Gear box

(*c*) Propeller shaft

(*d*) Differential

(*e*) Live Axle

(*a*) **Clutch:** This component enables the engine to keep disconnected from road wheels. The rotary motion available at the crankshaft is not transferred to road wheels. It allows the transfer of motion when desired by the driver of the automobile. It also allows the transfer of motion gradually so that the vehicle starts moving gradually. It works on the principle of friction.

(*b*) **Gear box:** It consists of a number of pairs of gear wheels. These transmit the motion available from the crankshaft, through clutch, at different speeds. This provides required leverage between engine and the road wheels. This leverage is variable to cope up the different conditions encountered during the movement of the vehicle.

Transmission System

(*c*) **Propeller shaft:** The third component of the transmission system which transfers motion from the gear box end to the differential end. The distance between the two can be large and therefore it is a shaft which is thin and long to connect the two.

(*d*) **Differential:** One of the requirements of the transmission system is to turn the motion through 90 degrees as the axis of the propeller shaft and live axle are at right angle to each other. This is performed by the differential through wheel and pinion arrangement. Another function performed by the differential is the variation in the speeds of inner and outer wheels when the vehicle is taking a turn.

(*e*) **Live axle:** The axle where motion from crankshaft of the engine is transferred is known as live axle. The other axle takes up only the load of the vehicle and therefore is termed as dead axle or simply the axle. The motion is generally transferred to rear axle but it can be transferred to the front axle or to both the axles. When the motion is transferred to both the axles it is known as four wheel drive.

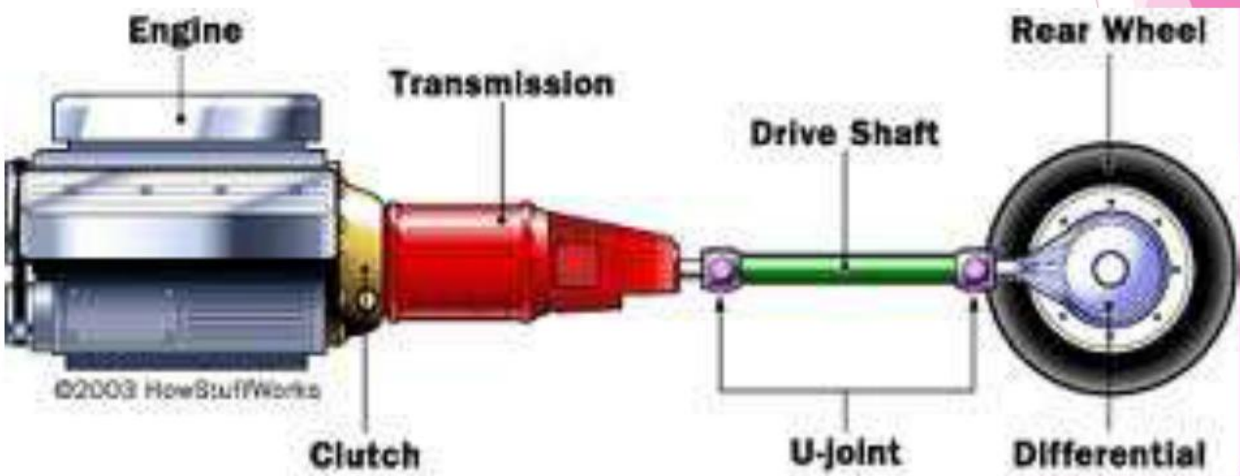
Finally motion is transferred to the road wheels at the two ends of the live axle. The wheels rotate and friction between their surface and road surface makes possible the movements of the vehicle on the road. In the forth coming chapters the components of transmission system are discussed in details.

Transmission System

Definition Of Transmission System :-

The mechanism that transmits the power developed by the engine of automobile to the engine to the driving wheels is called the TRANSMISSION SYSTEM (or POWER TRAIN).It is composed of -

- *Clutch*
- *The gear box*
- *Propeller shaft*
- *Universal joints*
- *Rear axle*
- *Wheel*
- *Tyres*



Transmission System

<u>The above requirements are fulfilled by the following main units of transmission system</u> :-

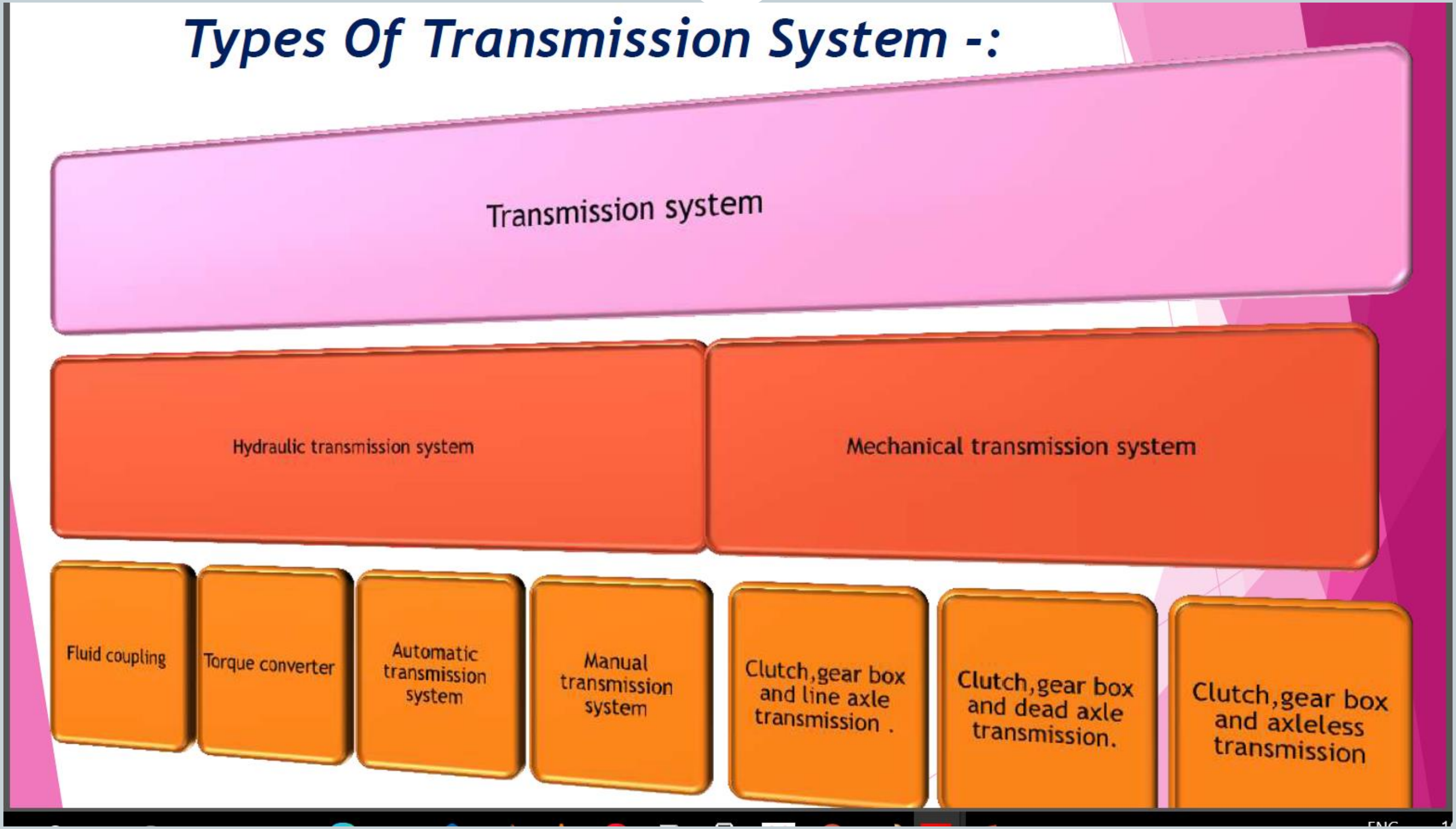
- *Clutch*
- *Gear Box*
- *Transfer Case*
- *Propeller Shaft and Universal Joints.*
- *Final Drive*
- *Differential*
- *Torque Tube*
- *Road Wheel*

Transmission System

Difference between tyre and wheel :-

Wheel	Tyre
A wheel is a device that allows heavy objects to be moved easily through rotating on an axle through its centre, facilitating movement or transportation while supporting a load (mass),or performing labor in machine.	While tyre is the outer part of the wheel made up with rubber and mostly use in vehicles for smooth movement

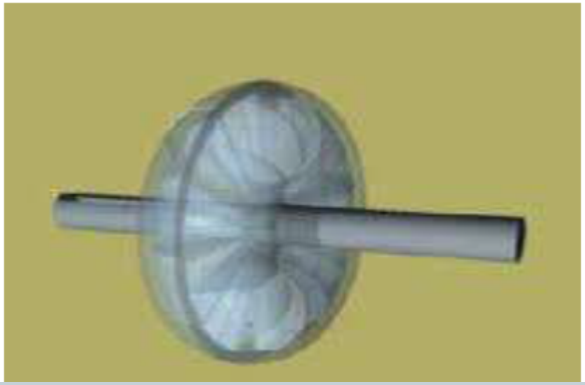
Transmission System



Transmission System

***Hydraulic transmission system*:-**

- ***Fluid coupling* -: A fluid coupling is a hydrodynamic device used to transmit rotating mechanical power.It has been used in automobile transmissions as an alternative to a mechanical clutch.**

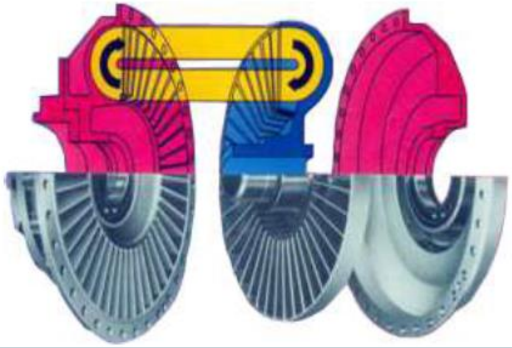


How fluid coupling can be act as a mechanical clutch ?

- *In automotive applications, the pump typically is connected to the flywheel of the engine The turbine is connected to the input shaft of the transmission. While the transmission is in gear, as engine speed increases torque is transferred from the engine to the input shaft by the motion of the fluid, propelling the vehicle . So, the behavior of the fluid coupling strongly resembles that of a mechanical clutch driving a manual transmission.*

Construction of a Fluid Coupling

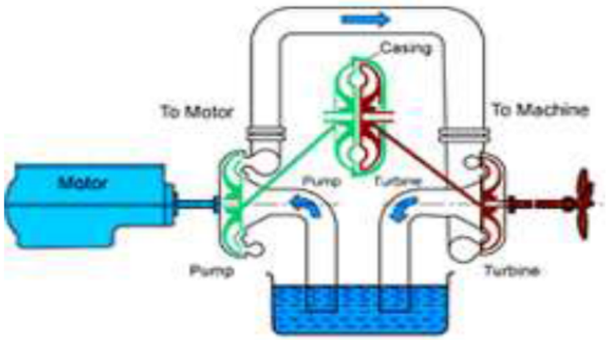
It consists of a pump-generally known as impeller and a turbine generally known as rotor, both enclosed suitably in a casing . They face each other with an air gap. The impeller is suitably connected to the prime mover while the rotor has a shaft bolted to it. This shaft is further connected to the driven machine through a suitable arrangement. Oil is filled in the fluid coupling from the filling plug provided on its body.



Transmission System

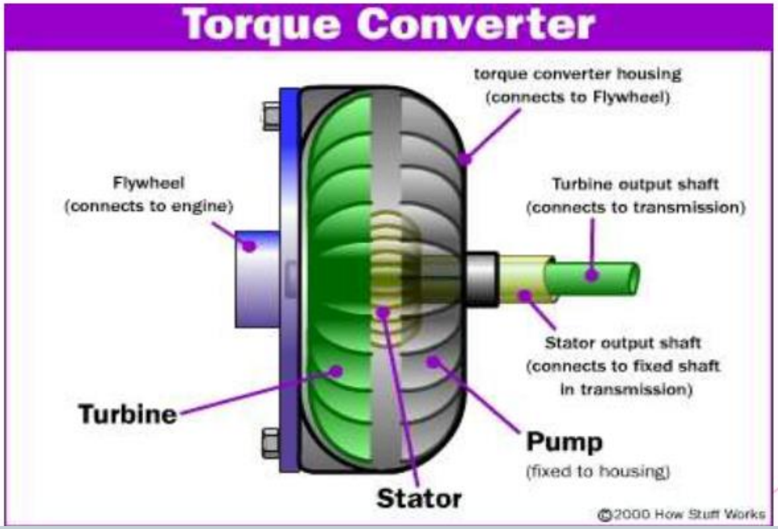
Operation principle of fluid Coupling

There is no mechanical interconnection between the impeller and the rotor and the power is transmitted by virtue of the fluid filled in the coupling. The impeller when rotated by the prime mover imparts velocity and energy to the fluid, which is converted into mechanical energy in the rotor thus rotating it. The fluid follows a closed circuit of flow from impeller to rotor through the air gap at the outer periphery and from rotor to impeller again through the air gap at the inner periphery. To enable the fluid to flow from impeller to rotor it is essential that there is difference in the "heat" between the two and thus it is essential that there is difference in R.P.M., known as slip between the two. As the slip increases more and more fluid can be transferred from the impeller to the rotor and more torque is transmitted.



Transmission System

<u>Torque Converter</u> :- *Torque converter is a hydraulic transmission which increases the torque of the vehicle reducing its speed . It provides a continuous variation of ratio from low to high. The key characteristic of a torque converter is its ability to multiply torque when there is a substantial difference between input and output rotational speed, thus providing the equivalent of a reduction gear. cars with an automatic transmission have no clutch that disconnects the transmission from the engine. So, they use an amazing device called a torque converter.*



Transmission System

Manual transmission system :-

- In this type of transmission system , the driver has to manually select and engage the gear ratios -:

Stages of Manual transmission

- ***Clutch fully depressed***

  The clutch is fully disengaged when the pedal is fully depressed. There will be no torque being transferred from the engine to the transmission and wheels. Fully depressing the clutch allows the driver to change gears or stop the vehicle.

- ***Clutch slips***

  The clutch slips is the point that vary between being fully depressed and released. The clutch slip is used to start the vehicle from a stand still. It then allows the engine rotation to adjust to the newly selected gear ratio gradually . It is recommended not to slip the clutch for a long time because a lot of heat is generated resulting in energy wastage.

- ***Clutch fully realeased***

  The clutch is fully engaged when the pedal is fully released. All the engine torque will be transmitted to the transmission. This results in the power being transmitted to the wheels with minimum loss.

Transmission System

Automatic transmission :-

- *Automatic transmission system is the most advanced system in which drives mechanical efforts are reduced very much and different speeds are obtained automatically. This system is generally also called hydramatic transmission. It contain epicyclic gear arrangement, fluid coupling and torque converter. In this planetary gears sets are placed in series to provide transmission. This type of transmission are used by Skoda ,Toyota , Lexus , etc*

- *Epicyclic gearing (planetry gearing) :- it is a gear system consisting of one or more outer gears, or planet gears, revolving about a central gear .By using epicyclic gear , different torque speed ratio can be obtained . It also compact the size of gear box.*

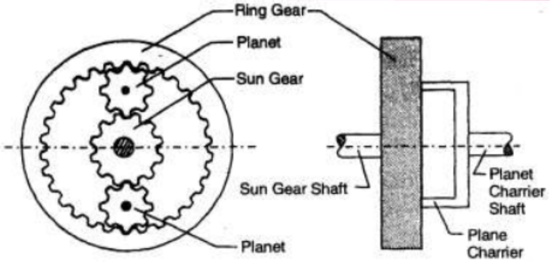


Fig. 4.4 Automatic Transmission System (Simple epicyclic gear set)

Transmission System

Stages of automatic transmission :-

- Park(P) :- selecting the park mode will lock the transmission, thus restricting the vehicle from moving.
- Reverse(R) :- selecting the reverse mode puts the car into reverse gear, allowing the vehicle to move backward.
- Neutral (N) :- selecting neutral mode disconnects the transmission from the wheel.
- Low (L) :- selecting the low mode will allow you to lower the speed to move on hilly and middy areas.
- Drive (D) :- selecting drive mode allows the vehicle to move and accelerate through a range of gears.

Transmission System

Comparison between manual transmission and automatic transmission :-

Manual transmission	Automatic transmission
Vehicles with manual transmission are usually cheaper .	Vehicles with automatic transmission are costlier than those of manual transmission.
Manual transmission has better fuel economy . This is because manual transmission has better mechanical and gear train efficiency.	Automatic transmission has not better fuel economy . This is because automatic transmission has not better mechanical and gear train efficiency as compare to those of automatic transmission.
Manual transmission offers the driver more control of the vehicle.	Automatic transmission does not offer the driver more control of the vehicle as compare to that of automatic transmission system.

Transmission System

POWER TRANSMISSION SYSTEM

Transmission is a speed reducing mechanism, equipped with several gears (Fig. 1). It may be called a sequence of gears and shafts, through which the engine power is transmitted to the tractor wheels. The system consists of various devices that cause forward and backward movement of tractor to suit different field condition. The complete path of power from the engine to the wheels is called *power train.*

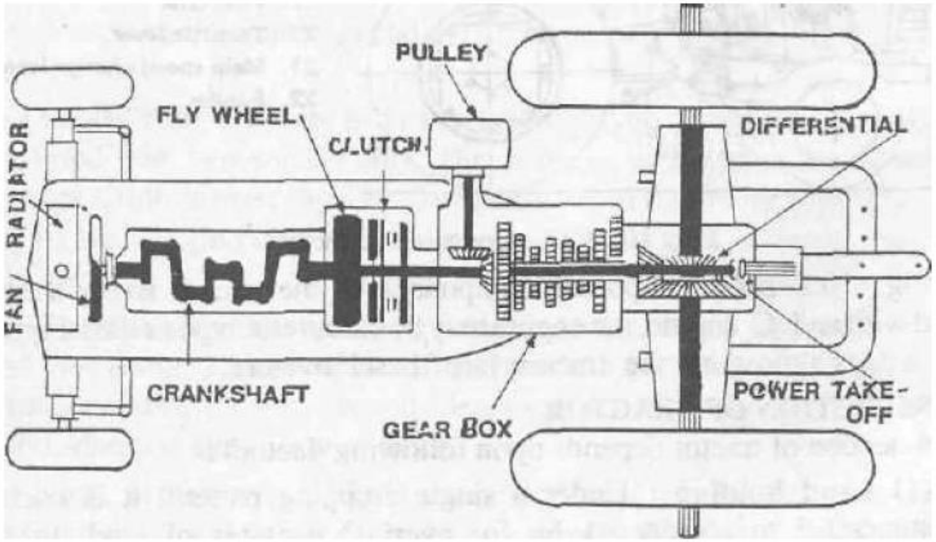


Fig 1 Power Transmission system of Tractor

Transmission System

Function of power transmission system:

(i) to transmit power from the engine to the rear wheels of the tractor, (ii) to make reduced speed available, to rear wheels of the tractor, (ii) to alter the ratio of wheel speed and engine speed in order to suit the field conditions and (iv) to transmit power through right angle drive, because the crankshaft and rear axle are normally at right angles to each other.

The power transmission system consists of:

(a) Clutch	(b) Transmission gears	(c) Differential
(d) Final drive	(e) Rear axle	(f) Rear wheels.

Combination of all these components is responsible for transmission of power.

Transmission System

DIFFERENTIAL UNIT AND FINAL DRIVE

Differential: *Differential unit* is a special arrangement of gears to permit one of the rear wheels of the tractor to rotate slower or faster than the other. While turning the tractor on a curved path, the inner wheel has to travel lesser the tractor to move faster than the other at the turning point. The output shaft coming from the gear box is provided with a bevel pinion at the end of the shaft (Fig. 6). The bevel pinion is in mesh with a large bevel wheel known as *crown wheel*. The main functions of *crown wheel* assembly are:

(i) to transmit power through right angle drive to suit the tractor wheels.

(ii) to reduce the speed of rotation.

The differential unit consists of: (i) differential casing (ii) differential pinion (iii) crown wheel (iv) half shaft and (v) bevel gear.

Transmission System

The differential casing is rigidly attached with the crown wheel and moves like one unit. Two pinions are provided inside the differential casing, such that they are carried round by the crown wheel but they are free to rotate also on their own shaft or stud. There are two or more bevel gears in mesh with differential pinion. One bevel pinion is at the end of each half shaft, which goes to the tractor rear wheel. Thus instead of crown wheel being keyed directly to a solid shaft between the tractor wheels, the drive is taken back from the indirect route through differential casing, differential pinion and half shaft of the tractor. When the tractor is moving in a straight line, the differential pinion do not rotate on the stub shaft but are solid with the differential casing. They drive the two bevel gears at the same speed and in the same direction as the casing and the crown wheel.

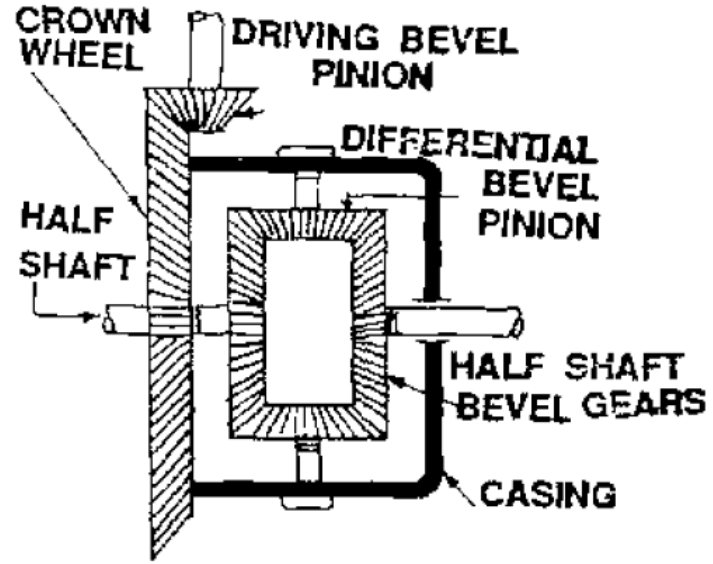


Fig. 6 Differential unit

Transmission System

Each differential pinion can move in two planes simultaneously. When it is carried round by the casing, it drives the half-shaft in the same direction but when it is rotated on its own shaft, it drives them in opposite direction i. e. rotation of differential pinion adds motion to one shaft and subtracts motion from the other shaft.

Differential lock: Differential lock is a device to join both half axles of the tractor so that even if one wheel is under less resistance, the tractor comes out from the mud etc as both wheels move with the same speed and apply equal traction.

Final drive: Final drive is a gear reduction unit in the power trains between the *differential* and the *drive wheels. Final drive* transmits the power finally to the rear axle and the wheels. The tractor rear wheels are not directly attached to the half shafts but the drive is taken through a pair of spur gears. Each half shaft terminates in a small gear, which meshes with a large gear called *bull gear.* The bull gear is mounted on the shaft, carrying the tractor rear wheel. The device for final speed reduction, suitable for tractor rear wheels is known as final drive mechanism.

Chapter 8
Cooling System

Introduction

We know that in the case of Internal Combustion engines, the combustion of air and fuel takes place inside the engine cylinder, and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result in the burning of oil film between the moving parts and may result in seizing or welding of the same.

So, this temperature must be reduced to about 150-200°C so that the engine will work most efficiently. Too much cooling is also not desirable since it reduces thermal efficiency. So, the object of the cooling system is to keep the engine running at its most efficient operating temperature.

It is to be noted that the engine is quite inefficient when it is cold. Hence, the cooling system is designed in such a way that it prevents cooling when the engine is warming up, and till it attains to maximum efficient operating temperature, then it starts cooling.

It is also to be noted that :

(a) About 20-25% of total heat generated is used for producing brake power (useful work).

(b) Cooling system is designed to remove 30-35% of total heat.

(c) Remaining heat is lost in friction and carried away by exhaust gases.

Cooling System

There are mainly two types of cooling systems :

(a) Air-cooled system, and

(b) Water-cooled system.

Air Cooled System

Air-cooled system is generally used in small engines say up to 15-20 kW and in aero-plane engines.

In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air.

Cooling System

The amount of heat dissipated to air depends upon:

(a) Amount of air flowing through the fins.

(b) Fin surface area.

(c) Thermal conductivity of metal used for fins.

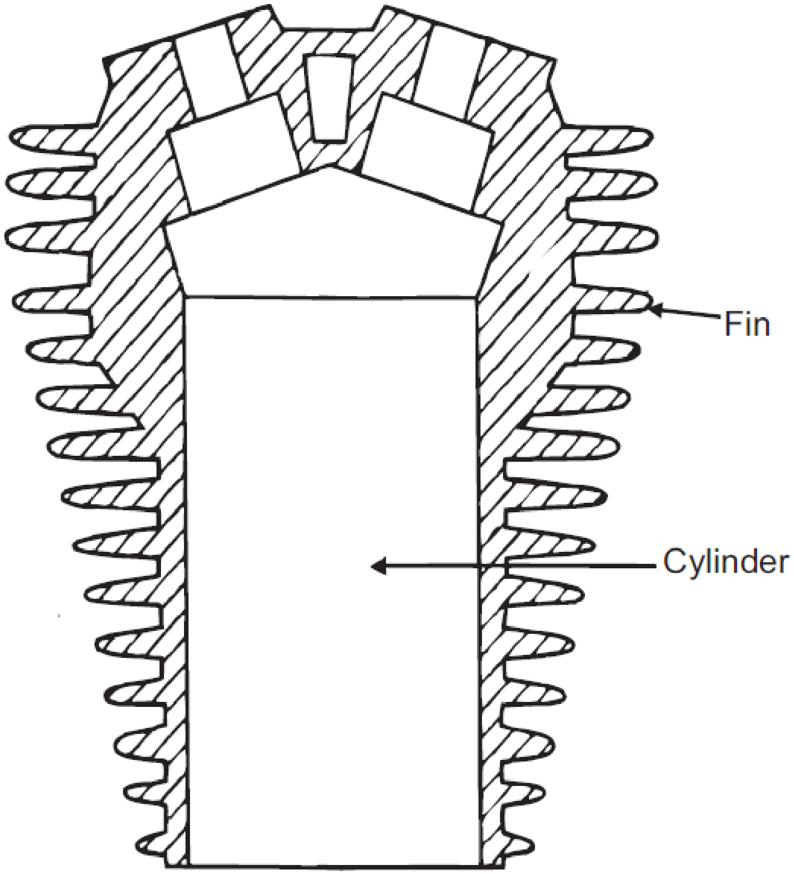


Figure 1 : Cylinder with Fins

Cooling System

Advantages of Air-Cooled System

The following are the advantages of air-cooled system :

(a) Radiator/pump is absent hence the system is light.

(b) In case of a watercooling system there are leakages, but in this case, there are no leakages.

© Coolant and antifreeze solutions are not required.

(d) This system can be used in cold climates, where if water is used it may freeze.

Disadvantages of Air-Cooled System

(a) Comparatively it is less efficient.

(b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

Cooling System

WATER COOLING SYSTEM

In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. The water when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again recirculated through the water jackets.

Types of Water Cooling System

There are two types of water cooling system:

Cooling System

Thermo Siphon System

In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only.

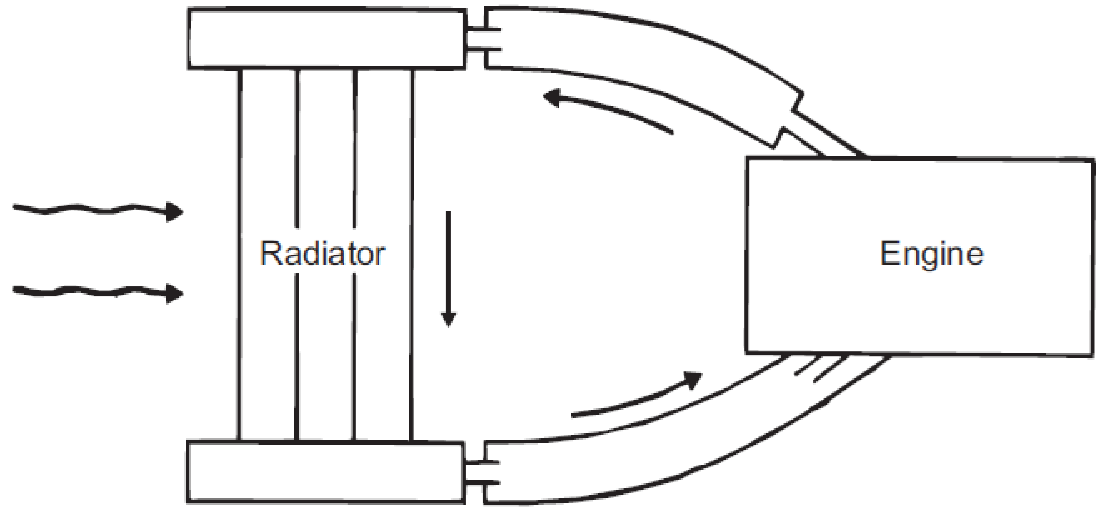


Figure2 : Thermo Siphon System of Cooling

Cooling System

Pump Circulation System

In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts.

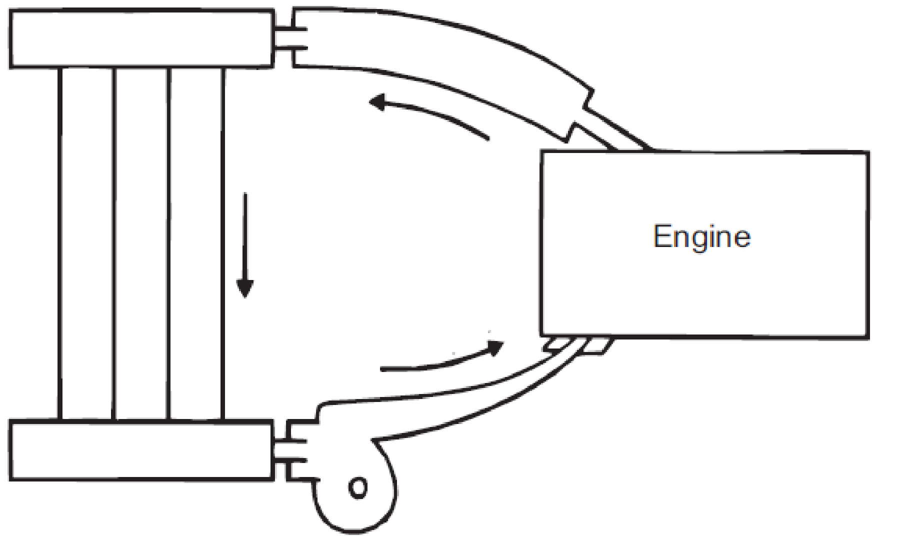


Figure 3 : Pump Circulation System

Cooling System

Water cooling system mainly consists of :

(a) Radiator,

(b) Thermostat valve,

(c) Water pump,

(d) Fan,

(e) Water Jackets, and

(f) Antifreeze mixtures.

Cooling System

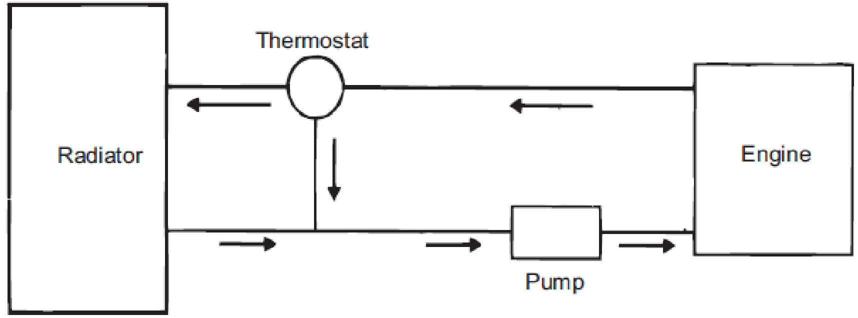


Figure 4 : Water Cooling System using Thermostat Valve

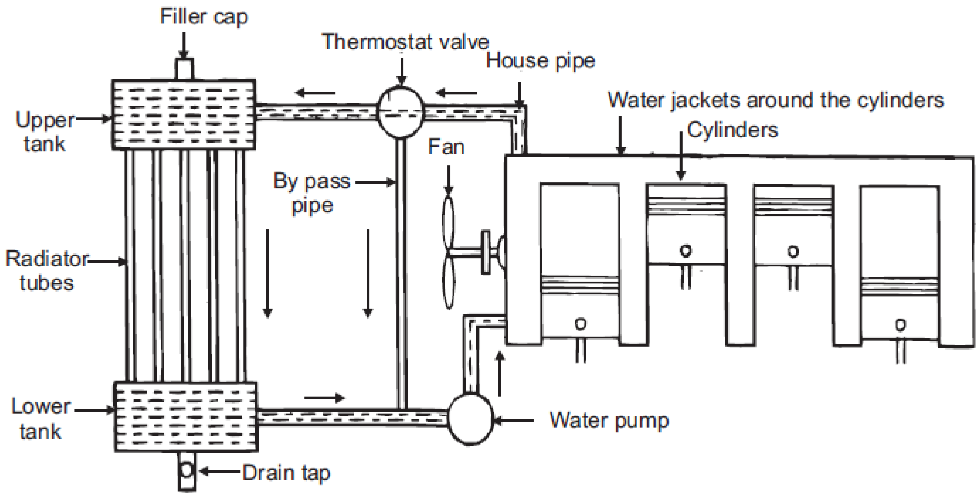


Figure 5: Water Cooling System of a 4-cylinder Engine

Cooling System

Radiator

It mainly consists of an upper tank and lower tank and between them is a core. The upper tank is connected to the water outlets from the engines jackets by a hose pipe and the lover tank is connect to the jacket inlet through water pump by means of hose pipes.

There are 2-types of cores :

(a) Tubular

(b) Cellular as shown.

When the water is flowing down through the radiator core, it is cooled partially by the fan which blows air and partially by the air flow developed by the forward motion of the vehicle.

As shown through water passages and air passages, wafer and air will be flowing for cooling purpose.

It is to be noted that radiators are generally made out of copper and brass and their joints are made by soldering.

Cooling System

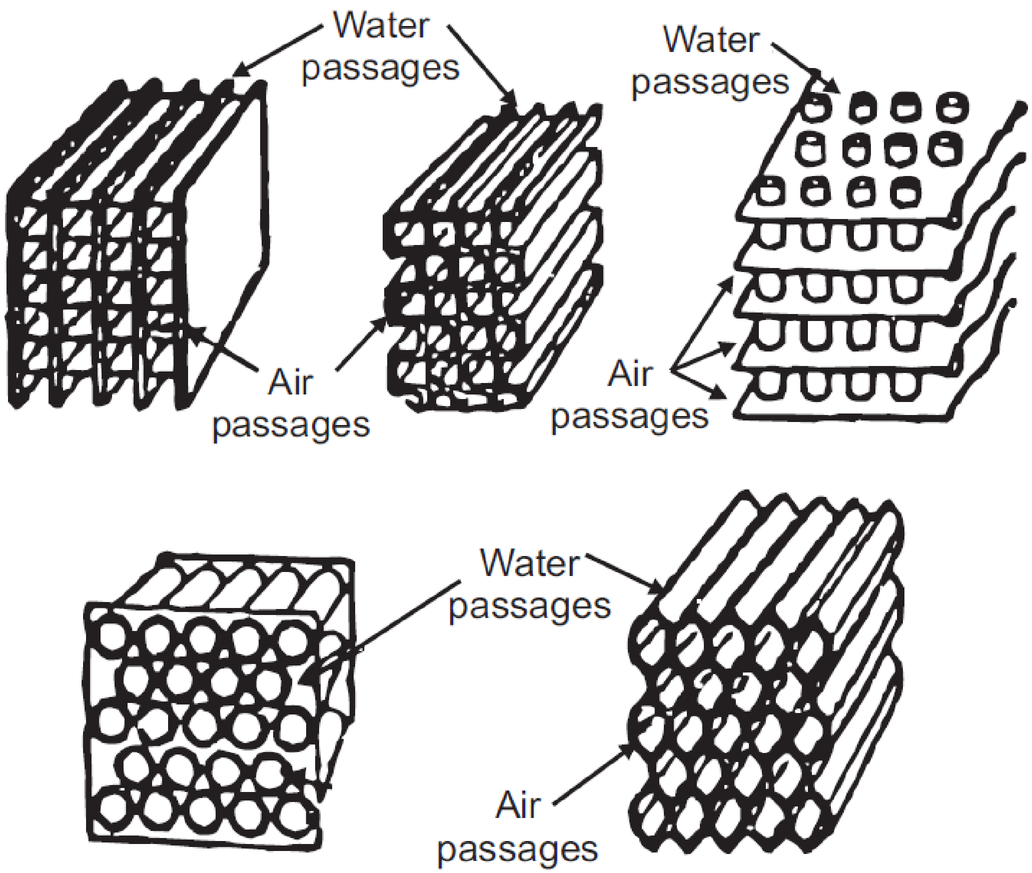


Figure 6: Types of Cores (a) Tabullar Radiator Sections and (b) Circullar Radiator Sections

Cooling System

Thermostat Valve

It is a valve which prevents flow of water from the engine to radiator, so that engine readily reaches to its maximum efficient operating temperature. After attaining maximum efficient operating temperature, it automatically begins functioning. Generally, it prevents the water below 70°C.

Cooling System

Figure 7 shows the Bellow type thermostat valve which is generally used.

It contains a bronze bellow containing liquid alcohol. Bellow is connected to the butterfly valve disc through the link.

When the temperature of water increases, the liquid alcohol evaporates and the bellow expands and in turn opens the butterfly valve, and allows hot water to the radiator, where it is cooled.

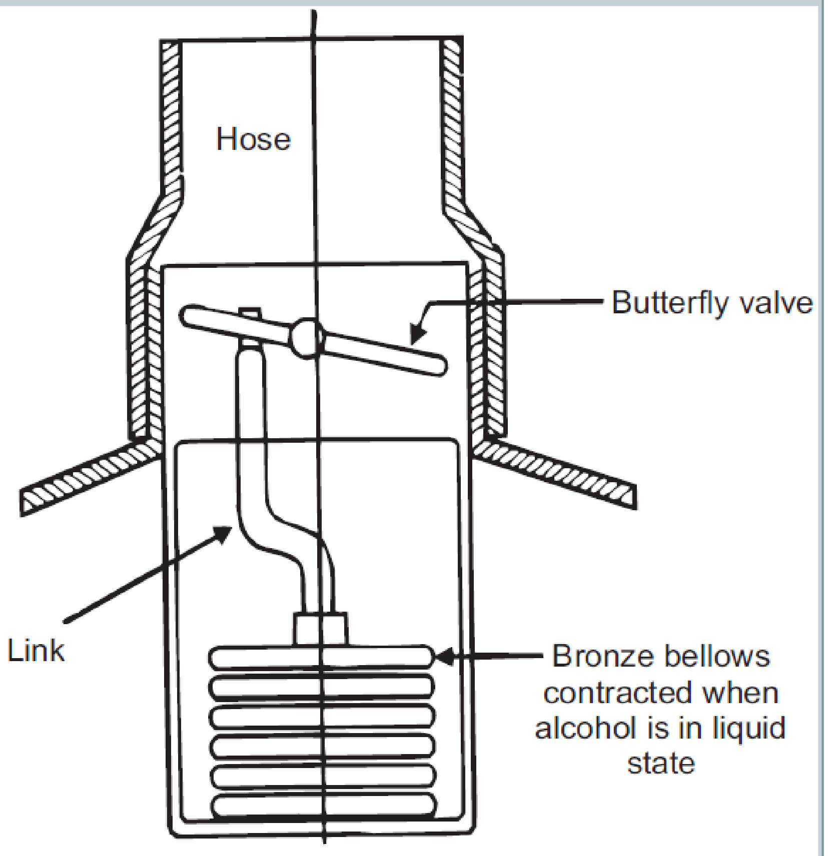


Figure 7 : Thermostat Valve

Cooling System

Water Pump

It is used to pump the circulating water. Impeller type pump will be mounted at the front end.

Pump consists of an impeller mounted on a shaft and enclosed in the pump casing. The pump casing has inlet and outlet openings. The pump is driven by means of engine output shaft only through belts. When it is driven water will be pumped.

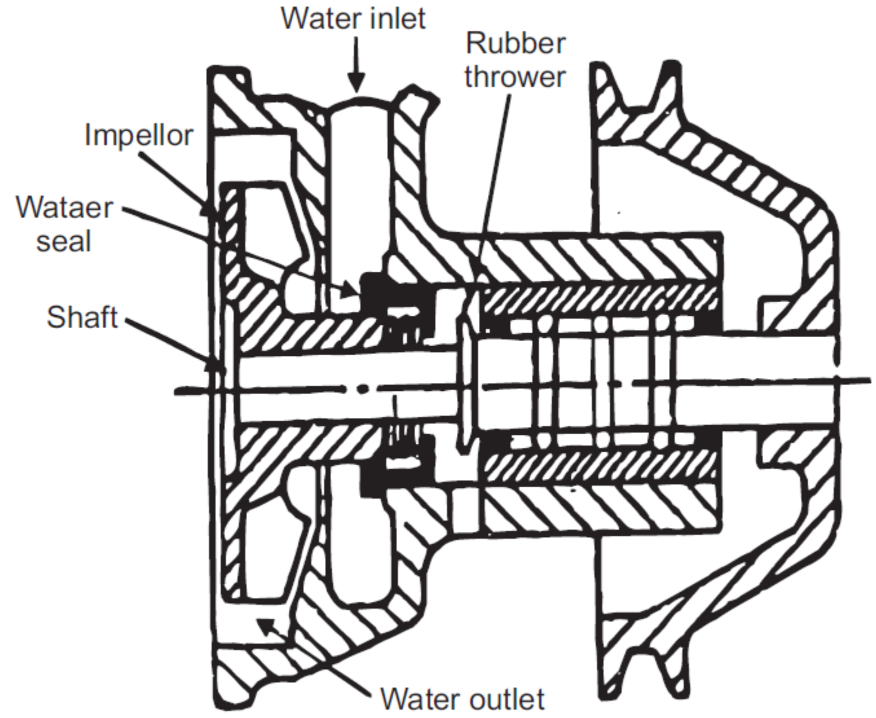


Figure 8 : Water Pump

Cooling System

Fan

It is driven by the engine output shaft through same belt that drives the pump. It is provided behind the radiator and it blows air over the radiator for cooling purpose.

Cooling System

Water Jackets

Cooling water jackets are provided around the cylinder, cylinder head, valve seats and any hot parts which are to be cooled. Heat generated in the engine cylinder, conducted through the cylinder walls to the jackets. The water flowing through the jackets absorbs this heat and gets hot. This hot water will then be cooled in the radiator (Referred Figure 9).

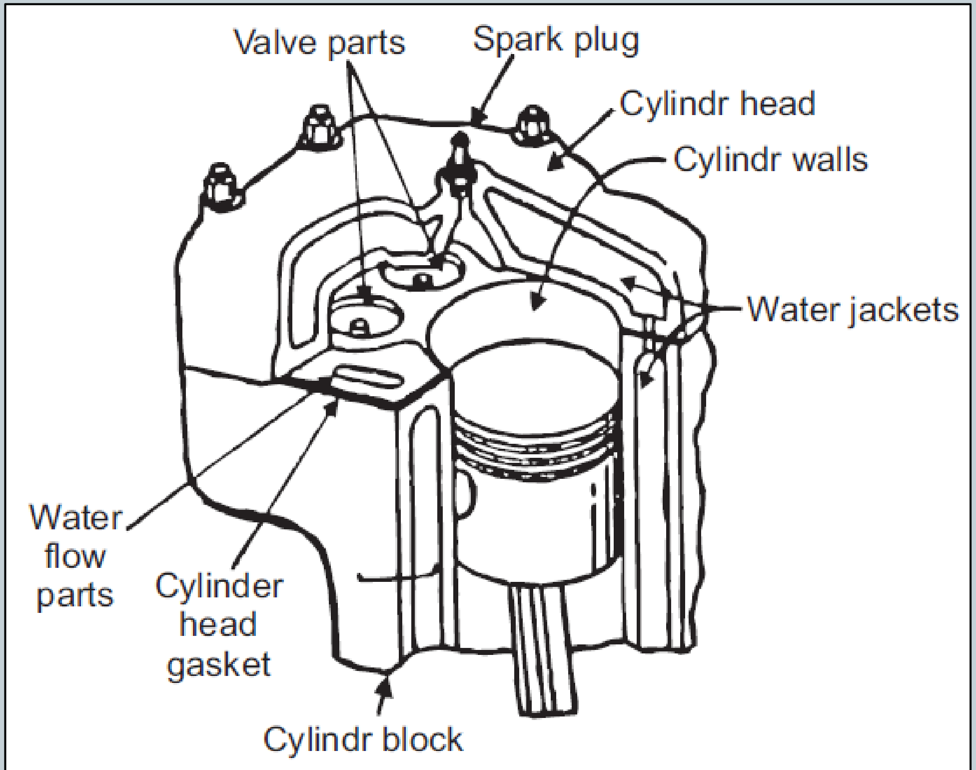


Figure 9 : Water Jackets

Cooling System

Antifreeze Mixture

In western countries if the water used in the radiator freezes because of cold climates, then ice formed has more volume and produces cracks in the cylinder blocks, pipes, and radiator. So, to prevent freezing antifreeze mixtures or solutions are added in the cooling water.

The ideal antifreeze solutions should have the following properties :

(a) It should dissolve in water easily.

(b) It should not evaporate.

(c) It should not deposit any foreign matter in cooling system.

(d) It should not have any harmful effect on any part of cooling system.

(e) It should be cheap and easily available.

(f) It should not corrode the system.

No single antifreeze satisfies all the requirements. Normally following are used as antifreeze solutions :

(a) Methyl, ethyl and isopropyl alcohols.

(b) A solution of alcohol and water.

(c) Ethylene Glycol.

(d) A solution of water and Ethylene Glycol.

(e) Glycerin along with water, etc.

Cooling System

Advantages

(a) Uniform cooling of cylinder, cylinder head and valves.

(b) Specific fuel consumption of engine improves by using water cooling system.

(c) If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.

(d) Engine is less noisy as compared with air cooled engines, as it has water for damping noise.

Disadvantages

(a) It depends upon the supply of water.

(b) The water pump which circulates water absorbs considerable power.

(c) If the water cooling system fails then it will result in severe damage of engine.

(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.

Chapter 9
Lubrication System

Introduction

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

PURPOSE OF LUBRICATION

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

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

Lubrication System

(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 System

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

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

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

Lubrication System

TYPES OF LUBRICANTS

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

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

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

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

Lubrication System

ENGINE LUBRICATING SYSTEM

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

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

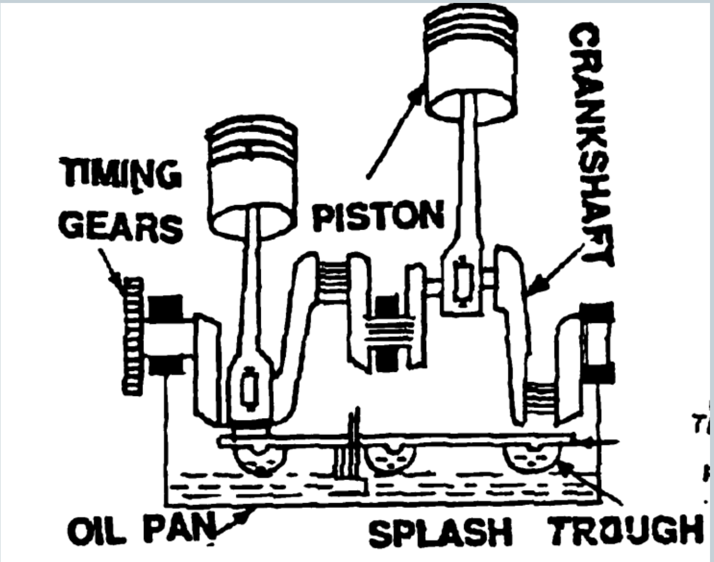
There are three common systems of lubrication used on stationary engines, tractor engines and automobiles:

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

Lubrication System

SPLASH SYSTEM

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



Lubrication System

This system is usually used on single cylinder engine with closes crankcase. For effective functioning of the engine, proper level of oil maintained in the oil pan.

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

Lubrication System

FORCED FEED SYSTEM

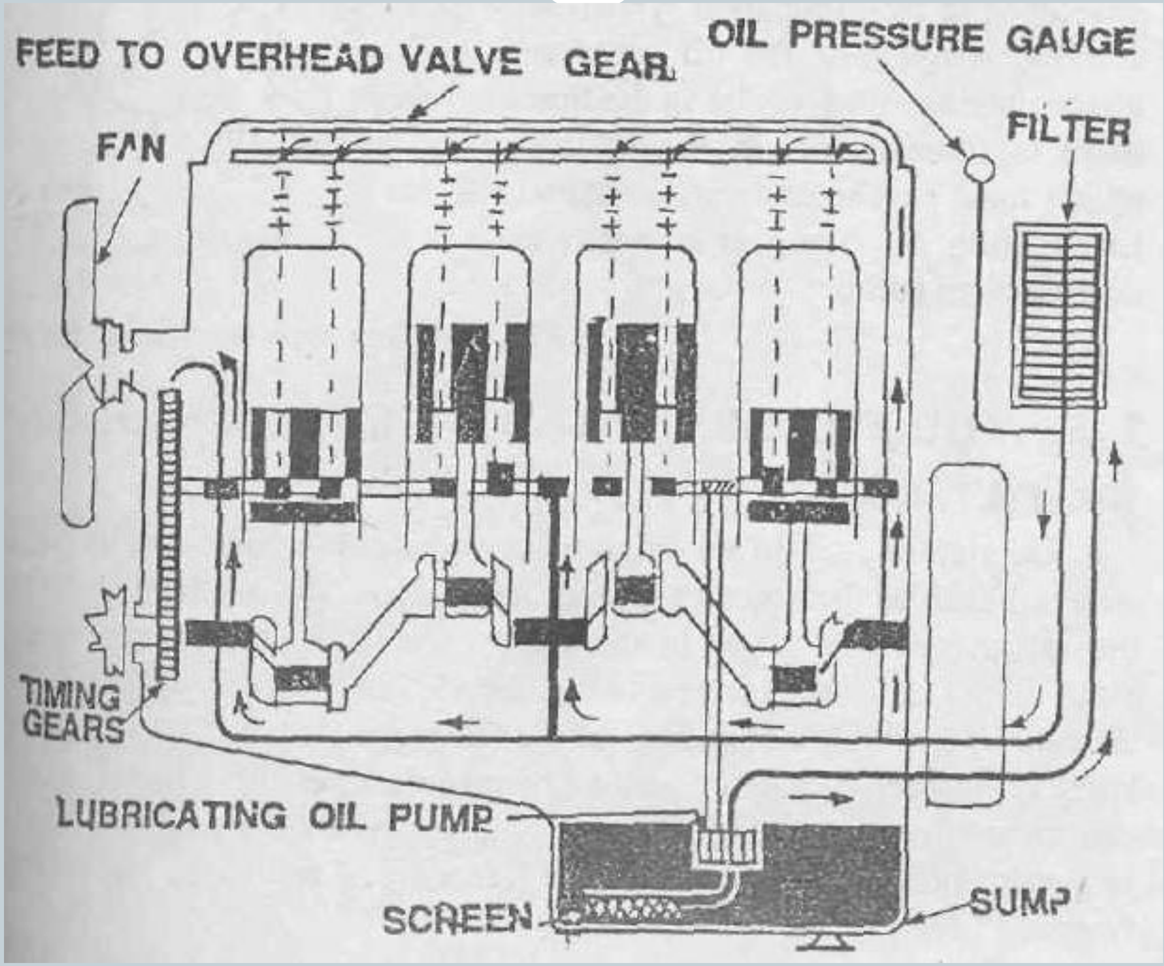
In this system, the oil is pumped directly lo the crankshaft, connecting rod, piston pin, timing gears and camshaft of the engine through suitable paths of oil. Usually the oil first enters the main gallery, which may be a pipe or a channel in the crankcase casting. From this pipe, it goes to each of the main bearings through holes. From main bearings, it goes to big end bearings of connecting rod through drilled holes in the crankshaft. From there, it goes to lubricate the walls, pistons and rings. There is separate oil gallery to lubricate timing gears.

Lubrication System

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.

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

Lubrication System



Lubrication System

TROUBLES IN LUBRICATION SYSTEM

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

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

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

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

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

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

Lubrication System

CARE AND MAINTENANCE OF LUBRICATION SYSTEM

The following are few suggestions for good lubrication system:

A good design of oil circulation system should be chosen.

Correct grade of lubricant ensures long and trouble free service.

Oil should be maintained at desired level in the oil chamber.

Oil should be cleaned regularly and after specified period of use, old filters should be replaced by new filters.

Connections, pipings, valves and pressure gauge should be checked regularly.

Oil should be changed regularly after specified interval of time. Before putting the new oil, the crankcase should be cleaned and flushed well with a flushing oil.

Precautions should be taken to keep the oil free from dust and water.

Chapter 10
Battery Ignition System

The internal combustion engine generates power by burning a mixture of air and fuel in its cylinders. In the gasoline engine, electric sparks must be generated to ignite the air-fuel mixture after the pistons in the cylinders have compressed it. In the diesel engine, on the other hand, the air in the cylinders is highly compressed. This causes it to become so hot, that when the fuel is sprayed into they cylinders, it ignites spontaneously.

Since, in the gasoline engine, the combustion process is started by the high-tension sparks generated at the spark plugs, some method must be used to provide the plugs with the necessary high-voltage current. This is done in one of two ways:

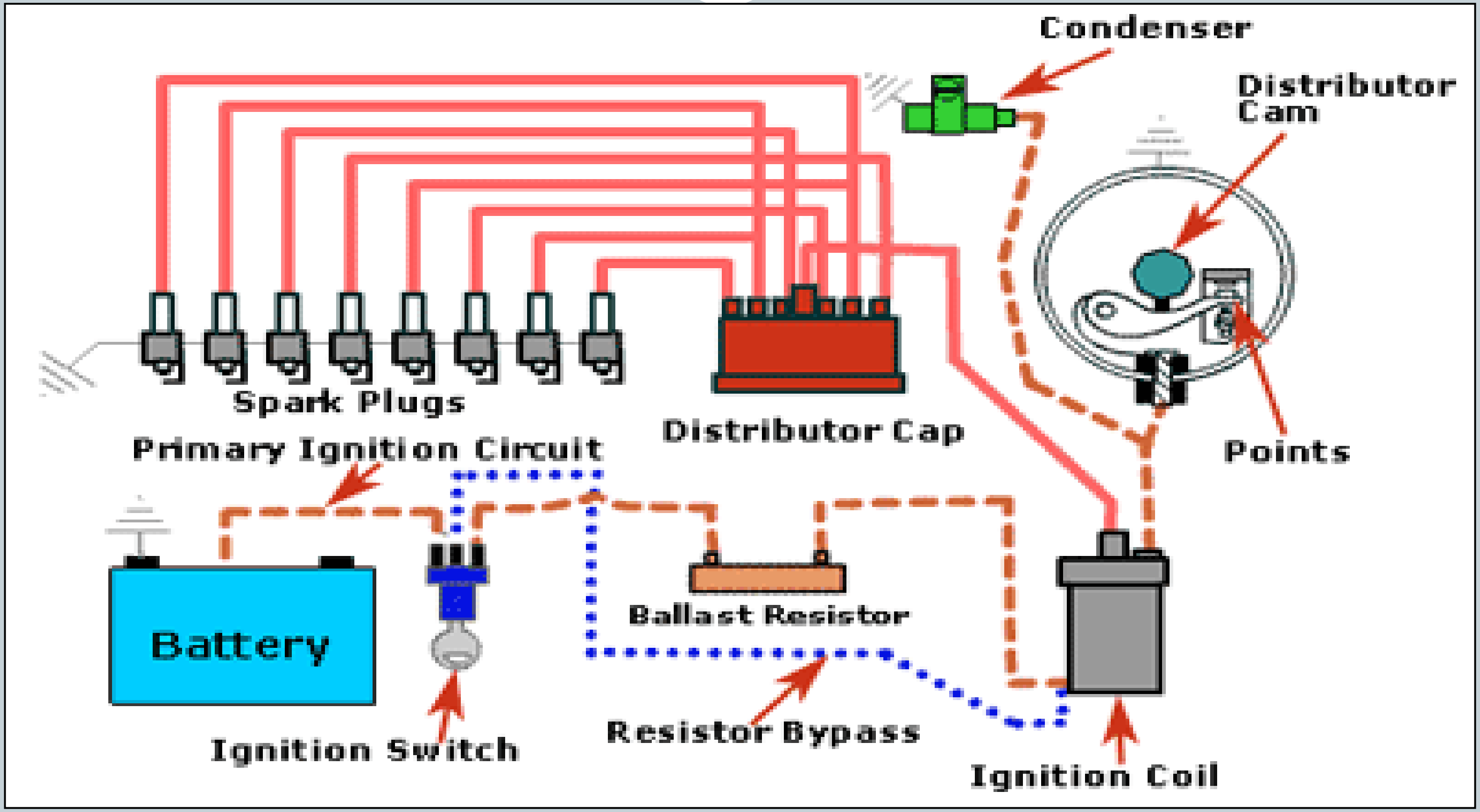
1. Magneto ignition.
2. Battery ignition.

Battery Ignition System

Since the magneto both generates the necessary EMF (electro- magnetic force) and raises it to a higher voltage, no battery is necessary in a magneto ignition system. For this reason, the magneto ignition system is widely used in small gasoline engines, such as those for motorcycles and lawn movers, portable engines and scooters etc.

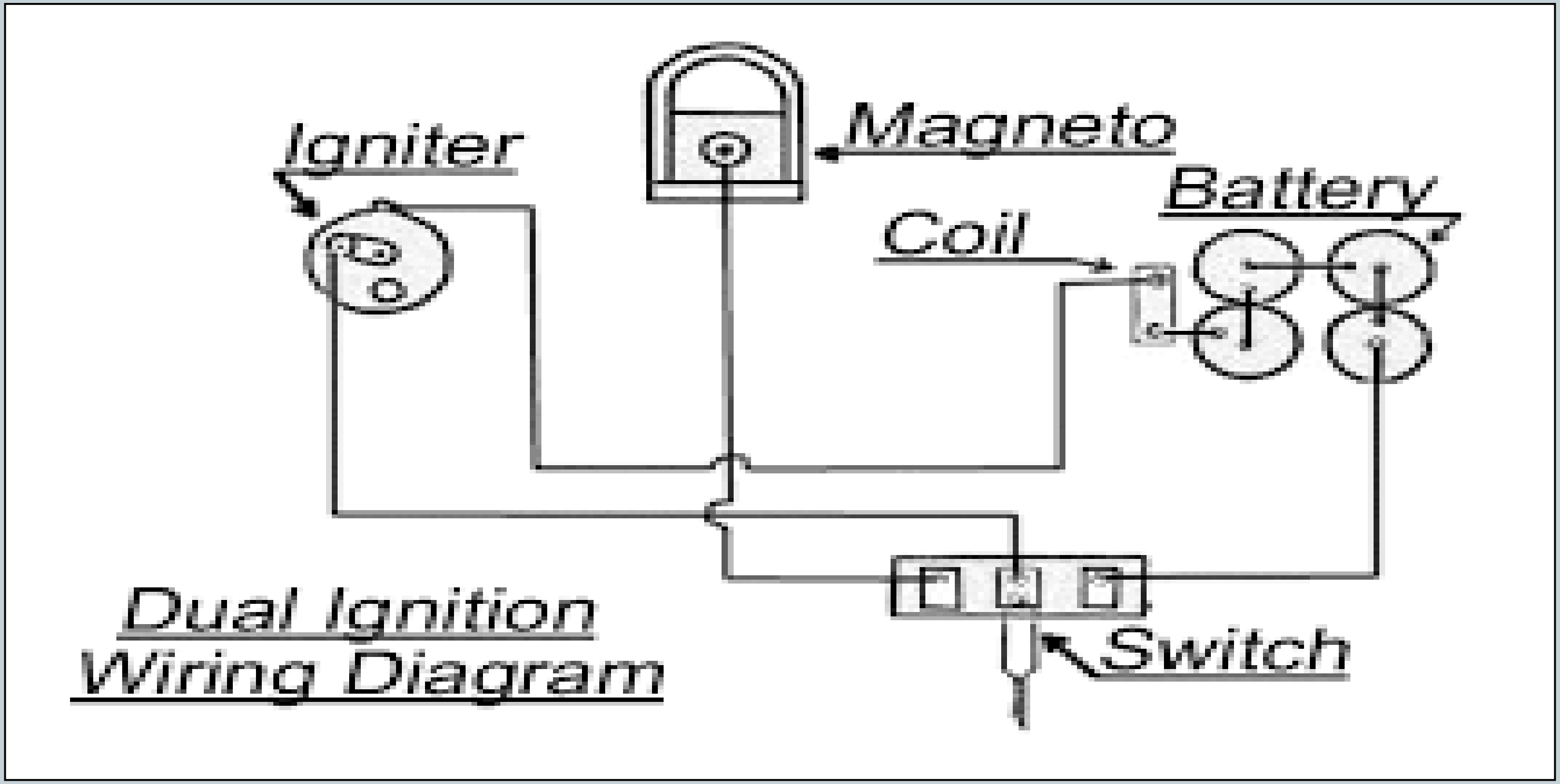
The battery ignition system raises the battery voltage to 10 kV or more by means of an ignition coil and supplies this high voltage to the spark plugs via a distributor and high-tension cords for spark generation. Modern automotive gasoline engines use this battery ignition system.

Battery Ignition System



Battery Ignition System

Battery Ignition System



Magneto Ignition System

Battery Ignition System

FUNCTIONS OF COMPONENT PARTS:-

1. Battery: -
Supplies low-voltage current (usually 12V) to the ignition coil.

2. Ignition coil: -
Converts the battery voltage to the high voltage required for ignition.

3. Distributor:-

Cam: Opens the breaker points depending on the crankshaft angle for each cylinder.

Breaker points: Interrupt the current flowing through the primary winding of the ignition coil in order to generate high-tension current in the secondary winding by electromagnetic induction.

Condenser (capacitor): Suppresses the spark generated between breaker points upon their opening to increase the secondary coil voltage.

Battery Ignition System

Centrifugal governor advancer: Advances the ignition timing according to the engine speed.

Vacuum advancer: Advances the ignition timing according to the engine load (intake manifold vacuum).

Rotor: Distributes the high-tension current generated by the ignition coil to each spark plug.

Distributor cap: Distributes high-tension current from the rotor to the high-tension cord of each cylinder.

4. **High-tension cords:-** Carry the high-tension current from the ignition coil to the spark plugs.

Battery Ignition System

Spark plugs:-

Discharge the high voltage applied to the electrodes for spark generation.

Construction: -

The spark plug consists mainly of the insulator, casing and center electrode.

Ceramic insulator: -

The ceramic insulator holds the center electrode and serves as the insulation between the center electrode and casing. Corrugations are provided on the ceramic insulator surface to extend the surface to distance between the terminal and casing for prevention of high-voltage flashover.

The insulator is made of high-purity alumina porcelain having excellent heat resistance, mechanical strength, dielectric strength at high temperatures and thermal conductivity.

Battery Ignition System

Casing:- The casing supports the ceramic insulator while at the same time serving as the means for mounting the spark plug to the engine.

Center electrode:- The center electrode consists of the following parts:

(i) Center shaft. Conducts the current and radiates away the heat produced by the electrodes.

(ii) Glass seal. Provides air tightness between the center shaft and ceramic insulator and bonds the center shafts and center electrode.

(iii) Resistor. Reduces ignition noise to reduce radio interference.

(iv) Copper core. Conducts heat from the electrode and insulator nose for quicker radiation.

(v) Center electrode. Generates the spark with the earth electrode.

Earth electrode. The earth electrode is made of the same material as the center electrode.U-groove, V-groove and other special electrodes have been developing for easier sparking to improve the ignition performance. (Details are explained later).

Battery Ignition System

Ignition coil:-

Description: - The ignition coil receives 12 V from the battery and generates a voltage sufficiently high (10 kV or more) to generate a strong spark at the spark plug gap.

In the ignition coil, the primary and secondary windings are wound around the core. These coils step up (increase) the battery voltage to a much higher voltage by electromagnetic induction (self-induction and mutual induction).

The initial ignition timing is the timing during engine idling when the ignition advancer mechanisms are not operating. The crankshaft angle at which this occurs is called the “basic crankshaft angle”, and refers to the proper moment during a certain stage of the compression cycle of the No.1 cylinder when ignition takes place.

The initial ignition timing is adjusted by physically changing the distributor mounting position relative to the engine: to do this, turn the distributor until the match mark on the crankshaft pulley lines up with the mark on the engine timing cover (this is checked using timing light).