UNIT- 5
Reciprocating machine Internal combustion engine

Internal combustion engine classifications

Internal combustion engines can be classified in a number of different ways:

1. Types of Ignition

(a) Spark Ignition (SI). An SI engine starts the combustion process in each cycle by use of a spark plug. The spark plug gives a high-voltage electrical Discharge between two electrodes which ignites the air-fuel mixture in the combustion chamber surrounding the plug. In early engine development, before the invention of the electric spark plug, many forms of torch holes
were used to initiate combustion from an external flame.
(b) Compression Ignition (CI). The combustion process in a CI engine starts when the air-fuel mixture self-ignites due to high temperature in the combustion chamber caused by high compression.

2. number of stroke

(a) Four-Stroke Cycle. A four-stroke cycle experiences four piston movements over two engine revolutions for each cycle.
(b) Two-Stroke Cycle. A two-stroke cycle has two piston movements over one revolution for each cycle.

3. Valve Location

(a) Valves in head (overhead valve), also called **I Head engine.**
(b) Valves in block (flat head), also called **L Head engine.** Some historic engines with valves in block had the intake valve on one side of the cylinder and the exhaust valve on the other side. These were called **T Head engines.**

4. Basic Design

(a) Reciprocating. Engine has one or more cylinders in which pistons reciprocate back and forth. The combustion chamber is located in the closed end of each cylinder. Power is delivered to a rotating output crankshaft by mechanical linkage with the pistons.
(b) Rotary. Engine is made of a block (stator) built around a large non-concentric rotor and crankshaft. The combustion chambers are built into the no rotating block.

5. Number of Cylinders

(a) Single Cylinder. Engine has one cylinder and piston connected to the crankshaft.
(b) Multi Cylinder.

6. Fuel Used

(a) Gasoline.
(b) Diesel Oil or Fuel Oil.
(c) Gas, Natural Gas, Methane.
(d) LPG.

9. Application

(a) Automobile, Truck, Bus.
(b) Locomotive.
(c) Stationary.
(d) Marine.
(e) Aircraft

1O. Type of Cooling

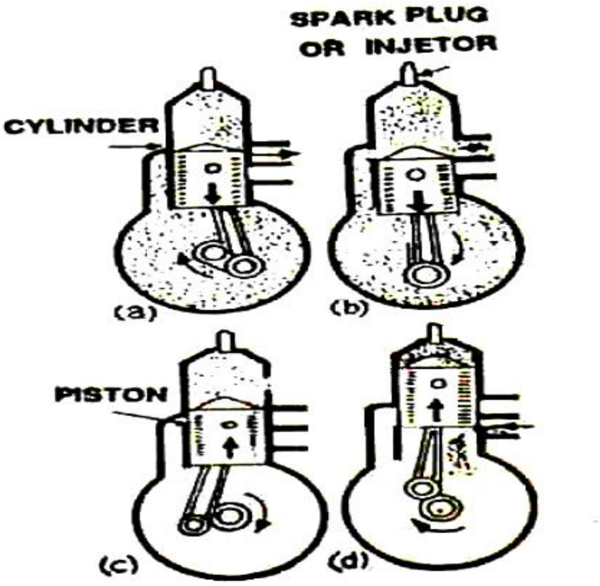
(a) Air Cooled.
(b) Liquid Cooled, Water Cooled.

Working of Internal combustion engine [conti.........] [RGPV Jan07,june 04]

[3]Two stroke diesel engine.

working:-

In two stroke cycle engines, the whole sequence of events i.e., suction, compression, power and exhaust are completed in two strokes of the piston i.e. one revolution of the crankshaft. There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is air tight in which the crankshaft rotates.



Upward stroke of the piston (suction + compression)

When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other. This traps the charge of air- fuel mixture drawn already in to the

cylinder. Further upward movement of the piston compresses the charge and also uncovers the suction port. Now fresh mixture is drawn through this port into the crankcase. Just before the end of this stroke, the mixture in the cylinder is ignited by a spark plug (fig 2 c &d). Thus, during this stroke both suction and compression events are completed.

Downward stroke (power + exhaust)

Burning of the fuel rises the temperature and pressure of the gases which forces the piston to move down the cylinder. When the piston moves down, it closes the suction port, trapping the fresh charge drawn into the crankcase during the previous upward stroke. Further downward movement of the piston uncovers first the exhaust port and then the transfer port. Now fresh charge in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases. During the downward stroke of the piston power and exhaust events are completed.

[4] TWO STROKE DIESEL ENGINE

Working

In two stroke cycle engines, the whole sequence of events i.e., suction, compression, power and exhaust are completed in two strokes of the piston i.e. one revolution of the crankshaft. There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is air tight in which the crankshaft rotates.

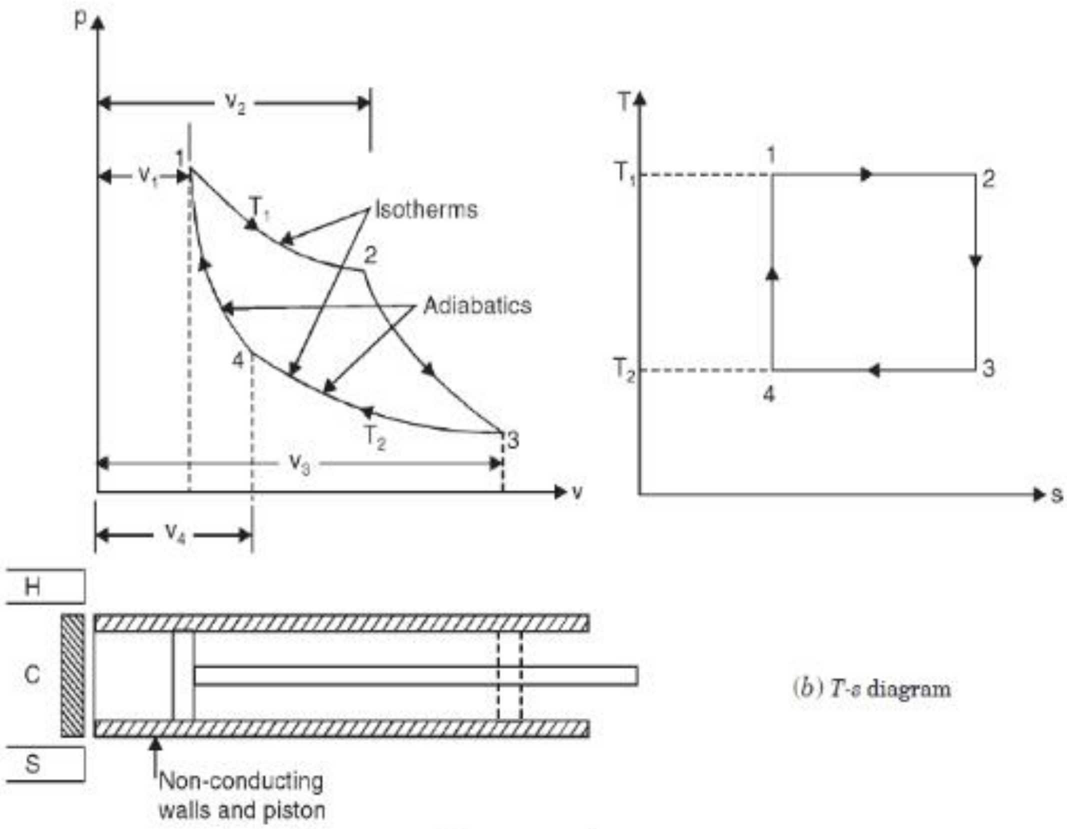
Upward stroke of the piston (suction + compression)

When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other. This traps the air drawn already in to the cylinder. Further upward movement of the piston compresses the air and also uncovers the suction port. Now fresh air is drawn through this port into the crankcase. Just before the end of this stroke, the air is compressed up to high pressure and fuel injector inject the diesel by fuel injector. at that time fuel is ignited. Thus, during this stroke both suction and compression events are completed.

THE CARNOT CYCLE [RGPV Jan08,June08, April 09]

This cycle has the *highest possible efficiency* and consists of four simple operations namely,
(*a*) Isothermal expansion
(*b*) Adiabatic expansion
(*c*) Isothermal compression
(*d*) Adiabatic compression.
The condition of the Carnot cycle may be imagined to occur in the following way :

One kg of a air is enclosed in the cylinder which (except at the end) is made of perfect no conducting material. A source of heat '*H*' is supposed to provide unlimited quantity of heat, no conducting cover '*C*' and a sump '*S*' which is of infinite capacity so that its temperature remains
Unchanged irrespective of the fact how much heat is supplied to it. The temperature of source *H* is *T*1 and the same is of the working substance. The working substance while rejecting heat to sump '*S*' has the temperature. *T*2 *i.e.*, the same as that of sump *S*.
Following are the *four stages* of the Carnot cycle. Refer Fig.



(*b*) *T-s* diagram

(*a*) Four stages of the carnot cycle

Stage (1). Line 1-2 [Fig. 13.1 (*a*)] represents the isothermal expansion which takes place at temperature *T*1 when source of heat *H* is applied to the end of cylinder. Heat supplied in this case is given by *RT*1 loge *r* and where *r* is the ratio of expansion.
Stage (2). Line 2-3 represents the application of non-conducting cover to the end of the cylinder. This is followed by the adiabatic expansion and the temperature falls from *T*1 to *T*2.
Stage (3). Line 3-4 represents the isothermal compression which takes place when sump

'*S*' is applied to the end of cylinder. Heat is rejected during this operation whose value is given by $RT_2 \log_e r$ where r is the ratio of compression.

Stage (4). Line 4-1 represents repeated application of non-conducting cover and adiabatic compression due to which temperature increases from T_2 to T_1.

It may be noted that ratio of expansion during isotherm 1-2 and ratio of compression during isotherm 3-4 must be equal to get a closed cycle.

Fig. 13.1 (*b*) represents the Carnot cycle on *T*-*s* coordinates.

Now according to law of conservation of energy,

Heat supplied = Work done + Heat rejected

Work done = Heat supplied – Heat rejected

$$= RT_1 \log_e r - RT_2 \log_e r$$

$$\text{Efficiency of cycle} = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{R \log_e r\,(T_1 - T_2)}{RT_1 \,.\, \log_e r}$$

$$= \frac{T_1 - T_2}{T_1}$$

Example 13.1. A Carnot engine working between 400°C and 40°C produces 130 kJ of work. Determine :

(i) The engine thermal efficiency.
(ii) The heat added.
(iii) The entropy changes during heat rejection process.

Solution. Temperature, $T_1 = T_2 = 400 + 273 = 673$ K

Temperature, $T_3 = T_4 = 40 + 273 = 313$ K

Work produced, $W = 130$ kJ.

(i) **Engine thermal efficiency,** η_{th}

$$\eta_{th.} = \frac{673 - 313}{673} = 0.535 \text{ or } 53.5\%. \quad \textbf{(Ans.)}$$

(*ii*) **Heat added :**

$$\eta_{th.} = \frac{\text{Work done}}{\text{Heat added}}$$

i.e.,

$$0.535 = \frac{130}{\text{Heat added}}$$

$$\therefore \quad \text{Heat added} = \frac{130}{0.535} = 243 \text{ kJ}. \quad \textbf{(Ans.)}$$

(*iii*) **Entropy change during the heat rejection process, $(S_3 - S_4)$:**

Heat rejected = Heat added – Work done

= 243 – 130 = 113 kJ

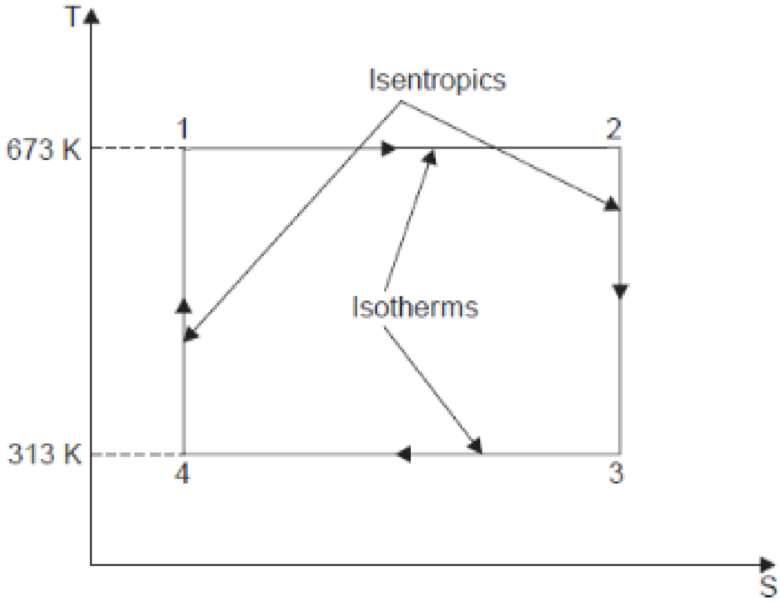


Fig. 13.2

$$\text{Heat rejected} = T_3 (S_3 - S_4) = 113$$

$$\therefore \quad (S_3 - S_4) = \frac{113}{T_3} = \frac{113}{313} = 0.361 \text{ kJ/K}. \quad \textbf{(Ans.)}$$

Constant volume or Otto cycle [RGPV Jan/feb08, Jan/feb07]

This cycle is so named as it was conceived by 'Otto'. On this cycle, petrol, gas and many types of oil engines work. It is the standard of comparison for internal combustion engines. Figs. 13.5 (*a*) and (*b*) shows the theoretical *p*-*V* diagram and *T*-*s* diagrams of this cycle respectively.

_ The point 1 represents that cylinder is full of air with volume $V1$, pressure $p1$ and absolute temperature $T1$.

_ Line 1-2 represents the *adiabatic compression* of air due to which *p*1, *V*1 and *T*1 change to
*p*2, *V*2 and *T*2, respectively.
_ Line 2-3 shows the *supply of heat* to the air *at constant volume* so that *p*2 and *T*2 change to *p*3 and *T*3 (*V*3 being the same as *V*2).
_ Line 3-4 represents the *adiabatic expansion* of the air. During expansion *p*3, *V*3 and *T*3 change to a final value of *p*4, *V*4 or *V*1 and *T*4, respectively.
_ Line 4-1 shows the *rejection of heat* by air at *constant volume* till original state (point 1) reaches.

Let compression ratio, $r_c\ (= r) = \frac{v_1}{v_2}$

and expansion ratio, $r_e\ (= r) = \frac{v_4}{v_3}$

(These *two ratios are same* in this cycle)

As $$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1}$$

Then, $$T_2 = T_1 \cdot (r)^{\gamma-1}$$

Similarly, $$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{\gamma-1}$$

or $$T_3 = T_4 \cdot (r)^{\gamma-1}$$

Inserting the values of T_2 and T_3 in equation (*i*), we get

$$\eta_{otto} = 1 - \frac{T_4 - T_1}{T_4 \cdot (r)^{\gamma-1} - T_1 \cdot (r)^{\gamma-1}} = 1 - \frac{T_4 - T_1}{r^{\gamma-1}(T_4 - T_1)}$$

$$= 1 - \frac{1}{(r)^{\gamma-1}}$$

This expression is known as the ***air standard efficiency of the Otto cycle.***

Some solve problem:

Example .The efficiency of an Otto cycle is 60% and γ = 1.5. What is the compression ratio?

Solution. Efficiency of Otto cycle, $\eta = 60\%$

Ratio of specific heats, $\gamma = 1.5$

Compression ratio, $r = ?$

Efficiency of Otto cycle is given by,

$$\eta_{Otto} = 1 - \frac{1}{(r)^{\gamma - 1}}$$

$$0.6 = 1 - \frac{1}{(r)^{1.5-1}}$$

or

$$\frac{1}{(r)^{0.5}} = 0.4 \quad \text{or} \quad (r)^{0.5} = \frac{1}{0.4} = 2.5 \quad \text{or} \quad r = 6.25$$

Hence, *compression ratio* = **6.25. (Ans.)**

Example 13.8. An engine of 250 mm bore and 375 mm stroke works on Otto cycle. The clearance volume is 0.00263 m3. The initial pressure and temperature are 1 bar and 50°C. If the maximum pressure is limited to 25 bar, find the following :

(i) The air standard efficiency of the cycle.
(ii) The mean effective pressure for the cycle.
Assume the ideal conditions.

Solution. Bore of the engine, D = 250 mm = 0.25 m
Stroke of the engine, L = 375 mm = 0.375 m ,Clearance volume, V_c = 0.00263 m^3
Initial pressure, p_1 = 1 bar ,Initial temperature, T_1 = 50 + 273 = 323 K

Consider **1 kg of air** (working substance) :

Heat supplied at constant volume = $c_v(T_3 - T_2)$.

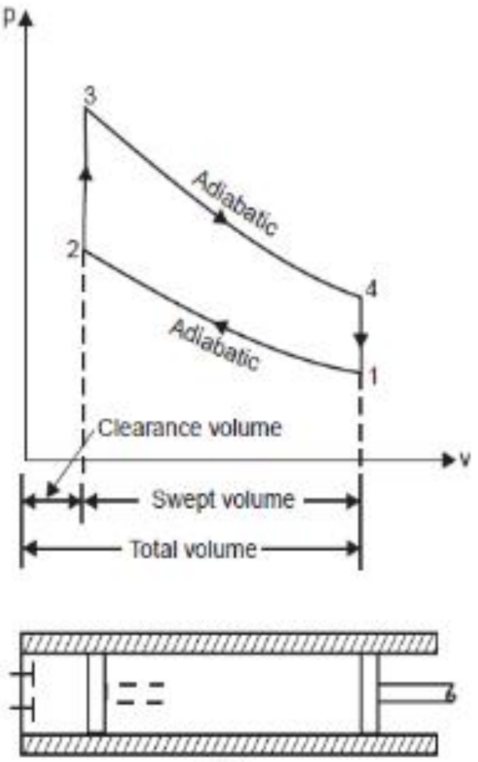
Heat rejected at constant volume = $c_v(T_4 - T_1)$.

But, work done = Heat supplied − Heat rejected

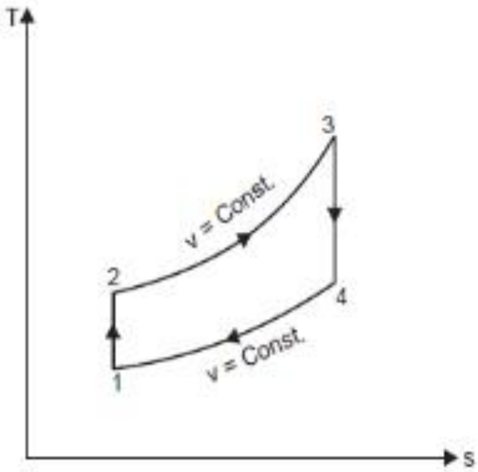
$$= c_v(T_3 - T_2) - c_v(T_4 - T_1)$$

$$\therefore \quad \text{Efficiency} = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{c_v(T_3 - T_2) - c_v(T_4 - T_1)}{c_v(T_3 - T_2)}$$

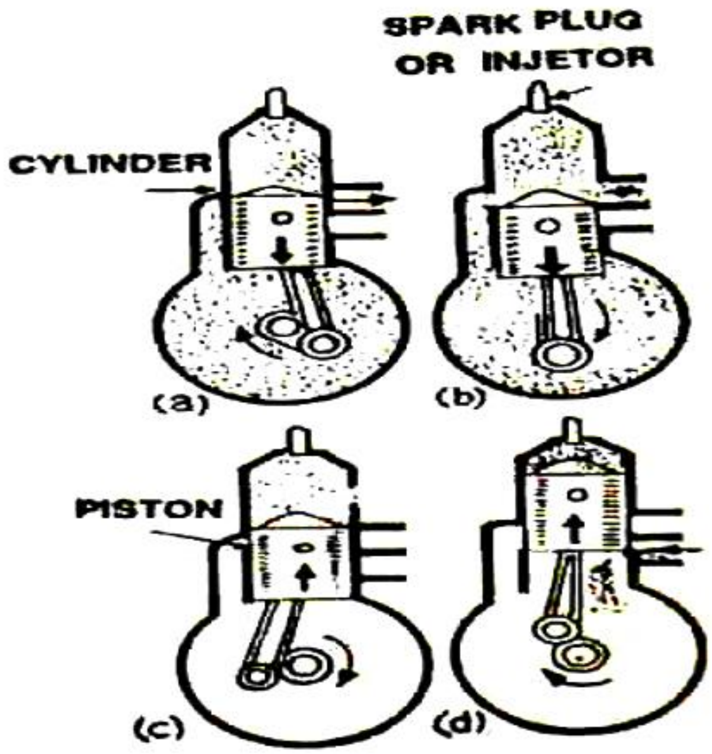
$$= 1 - \frac{T_4 - T_1}{T_3 - T_2} \quad ...(i)$$



(a)



(b)



Downward stroke (power + exhaust)

Burning of the fuel rises the temperature and pressure of the gases which forces the piston to move down the cylinder. When the piston moves down, it closes the suction port, trapping the fresh air drawn into the crankcase during the previous upward stroke. Further downward movement of the piston uncovers first the exhaust port and then the transfer port. Now fresh air in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases. During the downward stroke of the piston power and exhaust events are completed.

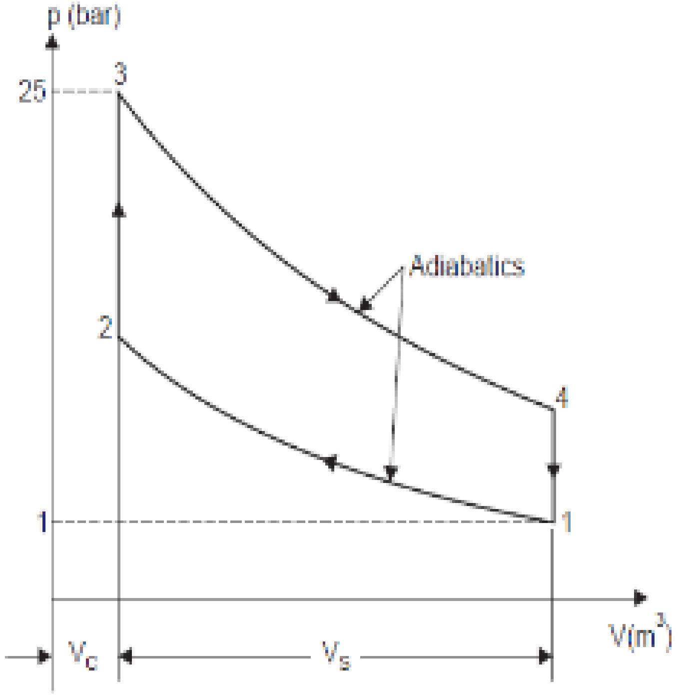


Fig. 13.6

Maximum pressure, $p_3 = 25$ bar

Swept volume, $V_s = \pi/4\ D^2L = \pi/4 \times 0.25^2 \times 0.375 = 0.0184\ m^3$

Compression ratio, $r = \dfrac{V_s + V_c}{V_c} = \dfrac{0.0184 + 0.00263}{0.00263} = 8.$

(*i*) **Air standard efficiency :**

The air standard efficiency of Otto cycle is given by

$$\eta_{Otto} = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(8)^{1.4-1}} = 1 - \frac{1}{(8)^{0.4}}$$

$$= 1 - 0.435 = \mathbf{0.565} \quad \textbf{or} \quad \mathbf{56.5\%.} \quad \textbf{(Ans.)}$$

(*ii*) **Mean effective pressure, p_m :**

For adiabatic (or isentropic) process 1-2

$$p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$$

$$p_2 = p_1 \left(\frac{V_1}{V_2}\right)^{\gamma} = 1 \times (r)^{1.4} = 1 \times (8)^{1.4} = 18.38 \text{ bar}$$

$\therefore$ Pressure ratio, $r_p = \dfrac{p_3}{p_2} = \dfrac{25}{18.38} = 1.36$

The mean effective pressure is given by

$$p_m = \frac{p_1 r[(r^{\gamma-1} - 1)(r_p - 1)]}{(\gamma - 1)(r - 1)} = \frac{1 \times 8\,[\{(8)^{1.4-1} - 1\}\,(1.36 - 1)]}{(1.4 - 1)\,(8 - 1)}$$

$$= \frac{8\,(2.297 - 1)(0.36)}{0.4 \times 7} = 1.334 \text{ bar}$$

Hence *mean effective pressure* = **1.334 bar. (Ans.)**

Constant pressure or diesel cycle [RGPV Jan08]

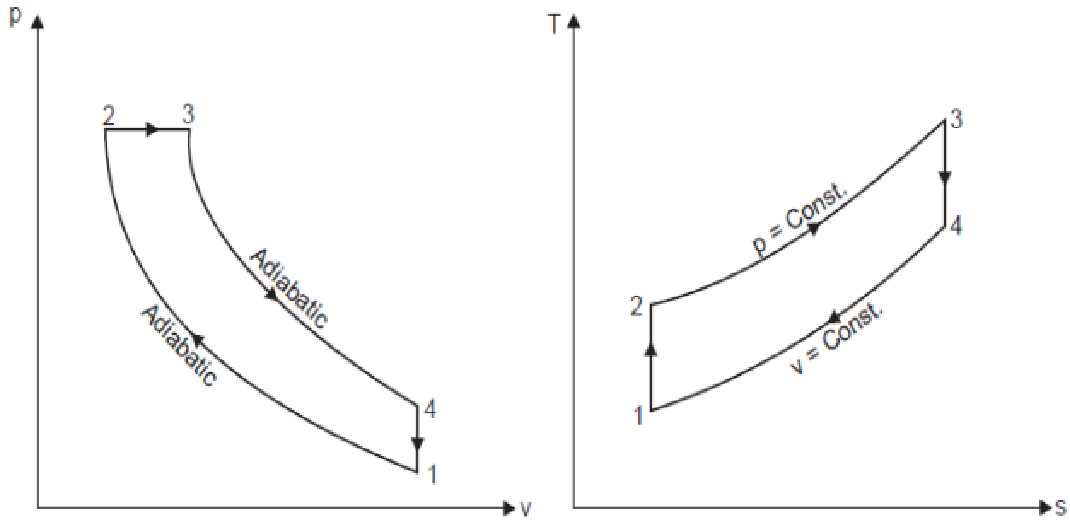
This cycle was introduced by Dr. R. Diesel in 1897. It differs from Otto cycle in that heat is supplied at constant pressure instead of at constant volume. Fig. 13.15 (a and b) shows the p-v and T-s diagrams of this cycle respectively.
This cycle comprises of the following **operations** :
(i) 1-2......Adiabatic compression.
(ii) 2-3......Addition of heat at constant pressure.
(iii) 3-4......Adiabatic expansion.
(iv) 4-1......Rejection of heat at constant volume.
Point 1 represents that the cylinder is full of air. Let p1, V1 and T1 be the corresponding pressure, volume and absolute temperature. The piston then compresses the air adiabatically (i.e.,
pV^{γ} = constant) till the values become p2, V2 and T2 respectively (at the end of the stroke) at point 2. Heat is then added from a hot body at a constant pressure. During this addition of heat let volume increases from V2 to V3 and temperature T2 to T3, corresponding to point 3. This point (3) is called the **point of cut-off**. The air then expands adiabatically to the conditions p4, V4 and T4 respectively corresponding to point 4. Finally, the air rejects the heat to the cold body at constant volume till the point 1 where it returns to its original state.
Consider 1 kg of air.

Heat supplied at constant pressure = cp(T3 – T2)

Heat rejected at constant volume = cv(T4 – T1)

Work done = Heat supplied – heat rejected

= cp(T3 – T2) – cv(T4 – T1)



$$\therefore \qquad \eta_{diesel} = \frac{\text{Work done}}{\text{Heat supplied}}$$

$$= \frac{c_p(T_3 - T_2) - c_v(T_4 - T_1)}{c_p(T_3 - T_2)}$$

$$= 1 - \frac{(T_4 - T_1)}{\gamma(T_3 - T_2)} \qquad \ldots(i) \left[\because \frac{c_p}{c_v} = \gamma\right]$$

Let compression ratio, $r = \frac{v_1}{v_2}$, and cut-off ratio, $\rho = \frac{v_3}{v_2}$ *i.e.*, $\frac{\text{Volume at cut-off}}{\text{Clearance volume}}$

Now, during *adiabatic compression 1-2,*

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = (r)^{\gamma-1} \quad \text{or} \quad T_2 = T_1 \cdot (r)^{\gamma-1}$$

During *constant pressure process 2-3,*

$$\frac{T_3}{T_2} = \frac{v_3}{v_2} = \rho \quad \text{or} \quad T_3 = \rho \cdot T_2 = \rho \cdot T_1 \cdot (r)^{\gamma-1}$$

During *adiabatic expansion 3-4*

$$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{\gamma-1}$$

$$= \left(\frac{r}{\rho}\right)^{\gamma-1} \qquad \left(\because \frac{v_4}{v_3} = \frac{v_1}{v_3} = \frac{v_1}{v_2} \times \frac{v_2}{v_3} = \frac{r}{\rho}\right)$$

$$\therefore \qquad T_4 = \frac{T_3}{\left(\frac{r}{\rho}\right)^{\gamma-1}} = \frac{\rho . T_1 (r)^{\gamma-1}}{\left(\frac{r}{\rho}\right)^{\gamma-1}} = T_1 . \rho^{\gamma}$$

By inserting values of T_2, T_3 and T_4 in eqn. (*i*), we get

$$\eta_{diesel} = 1 - \frac{(T_1 . \rho^{\gamma} - T_1)}{\gamma\,(\rho . T_1 . (r)^{\gamma-1} - T_1 . (r)^{\gamma-1})} = 1 - \frac{(\rho^{\gamma} - 1)}{\gamma (r)^{\gamma-1} (\rho - 1)}$$

$$\eta_{diesel} = 1 - \frac{1}{\gamma (r)^{\gamma-1}} \left[\frac{\rho^{\gamma} - 1}{\rho - 1}\right]$$

Some solve Problem :

Example. A diesel engine has a compression ratio of 15 and heat addition at constant pressure takes place at 6% of stroke. Find the air standard efficiency of the engine.
Take γ for air as 1.4.

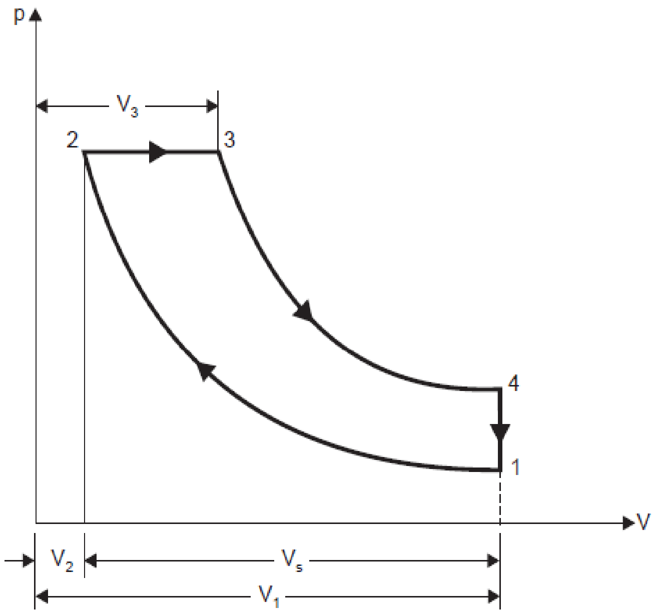


Fig. 13.16

Compression ratio, $r\left(=\frac{V_1}{V_2}\right) = 15$

γ for air = 1.4

Air standard efficiency of diesel cycle is given by

$$\eta_{diesel} = 1 - \frac{1}{\gamma(r)^{\gamma-1}}\left[\frac{\rho^\gamma - 1}{\rho - 1}\right]$$

where ρ = cut-off ratio = $\frac{V_3}{V_2}$

But $\quad V_3 - V_2 = \frac{6}{100} V_s \quad (V_s = \text{stroke volume})$

$$= 0.06\,(V_1 - V_2) = 0.06\,(15\,V_2 - V_2)$$

$$= 0.84\,V_2 \text{ or } V_3 = 1.84\,V_2$$

$\therefore$ $$\rho = \frac{V_3}{V_2} = \frac{1.84\,V_2}{V_2} = 1.84$$

Putting the value in eqn. (*i*), we get

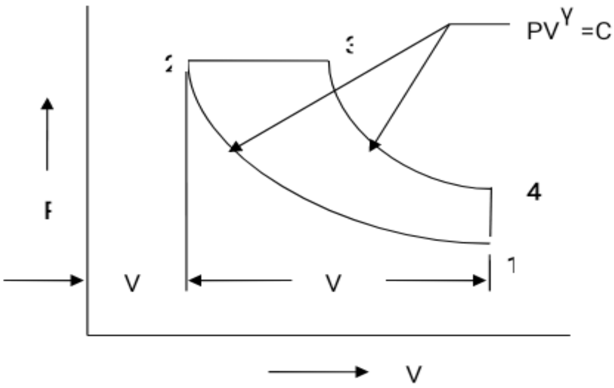
$$\eta_{diesel} = 1 - \frac{1}{1.4\,(15)^{1.4-1}}\left[\frac{(1.84)^{1.4} - 1}{1.84 - 1}\right]$$

$$= 1 - 0.2417 \times 1.605 = \mathbf{0.612 \text{ or } 61.2\%.} \quad \text{(Ans.)}$$

Example. Detrermine the compression ratio and air standard efficiency of a single cylinder diesel engine having a bore of 15 cm, stroke 20cm, clearance volume is 6% of the stroke volume and cut off takes place at 10 % of the stroke .

Solution.

Given D =15cm =0.15 m
L =20cm = 0.2 m
Swept volume =V_s = $(\pi/4)\times D^2L$
Vs =3534 cm^3 = 3.534×10^{-3} m^3
V_c =0.06×3534=212 cm^3= 2.12×10^{-4} m^3
Compression ratio = r = $(V_s+V_c)/V_c$ = 17.7



Fuel cut-off = 8% of stroke
Fuel cut off $\rho = V_3/V_2 = (V_c + 0.08V_s)/V_c = 2.33$
Air standard efficiency of diesel cycle=?
Air standard efficiency of the diesel cycle

$$\eta = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$$

$$\eta = 1 - \frac{1}{17.7^{1.4-1}}\left[\frac{2.33^{1.4}-1}{1.4(2.33-1)}\right]$$

η = 61.4% **Answer**

COMPARISON BETWEEN TWO STROKE AND FOUR STROKE ENGINES [RGPV Jan02, febe06, june 06,08 dec.08,08]

4-Stroke	2-Stroke
1. One power stroke for every two revolutions of the crankshaft.	One power stroke for each revolution of the crankshaft
2. There are inlet and exhaust valves in the engine.	There are inlet and exhaust ports instead of valves.
3. Crankcase is not fully closed and air tight. .	Crankcase is fully closed and air tight
4. Top of the piston compresses the charge.	Both sides of the piston compress the charge.
5. Size of the flywheel is comparatively larger.	Size of the flywheel is comparatively smaller.
6. Fuel is fully consumed.	Fuel is not fully consumed.
8. Thermal efficiency is high.	Thermal efficiency is comparatively low.
9. Removal or exhaust gases easy.	Removal of exhaust gases comparatively difficult.
10. Torque produced is even.	Torque produced is less even.
11. For a given weight, engine would give only half the power of two stroke	For same weight, two stroke engines gives twice the power that of four stroke engine.

COMPARISON OF DIESEL ENGINE WITH PETROL ENGINE

Diesel engine	petrol engine
i) It has got no carburettor, ignition coil and spark plug.	It has got carburettor, ignition coil & spark plug.
ii) Its compression ratio varies from 14:1 to 22:1	Its compression ratio varies from 5:1 to 8:1.
iii) It uses diesel oil as fuel.	It uses petrol (gasoline) or power kerosene as fuel.
iv) Only air is sucked in cylinder in suction stroke.	Mixture of fuel and air is sucked in the cylinder in suction stroke.
v) It has got 'fuel injection pump' and injector	It has got no fuel injection pump and injector, instead it has got carburettor and ignition coil.
vi) Fuel is injected in combustion chamber where burning of fuel takes places due to heat of compression.	Air fuel mixture is compressed in the combustion chamber when it is ignited by an electric spark.
vii) Thermal efficiency varies from 32 to38%	Thermal efficiency varies from 25 to 32%
viii) Engine weight per horse-power is high.	Engine weight per horsepower is comparatively low.
ix) Operating cost is low. Operating cost is high.	
x) Compression pressure inside the cylinder varies from 35 to 45 kg/cm2 and temperature is about 500°C.	Compression pressure varies from 6 to 10 kg/cm2 and temperature is above 260°C.

Otto Cycle	Diesel Cycle
In Otto cycle both heat addition and heat rejection take place at constant volume	In Diesel cycle heat addition take place at constant pressure While heat Rejection take place at constant volume
Efficiency depends only upon compression ratio.	Efficiency depends upon compression ratio and cut-off ratio.
Higher air standard efficiency	Lower air standard efficiency
$\eta_{Otto} = 1 - \frac{1}{(r)^{\gamma-1}}$	$\eta = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$

ENGINE COMPONENTS [RGPV Nov 07, Dec 07, Dec 02, jun2 02]

Internal combustion engine consists of a number of parts which are given below:

i) Cylinder: It is a part of the engine which confines the expanding gases and forms the combustion space. It is the basic part of the engine. It provides space in which piston operates to suck the air or air-fuel mixture. The piston compresses the charge and the gas is allowed to expand in the cylinder, transmitting power for useful work. Cylinders are usually made of high grade cast iron.

ii) Cylinder block: It is the solid casting body which includes the cylinder and water jackets (cooling fins in the air cooled engines).

iii) Cylinder head: It is a detachable portion of an engine which covers the cylinder and includes the combustion chamber, spark plugs or injector and valves.

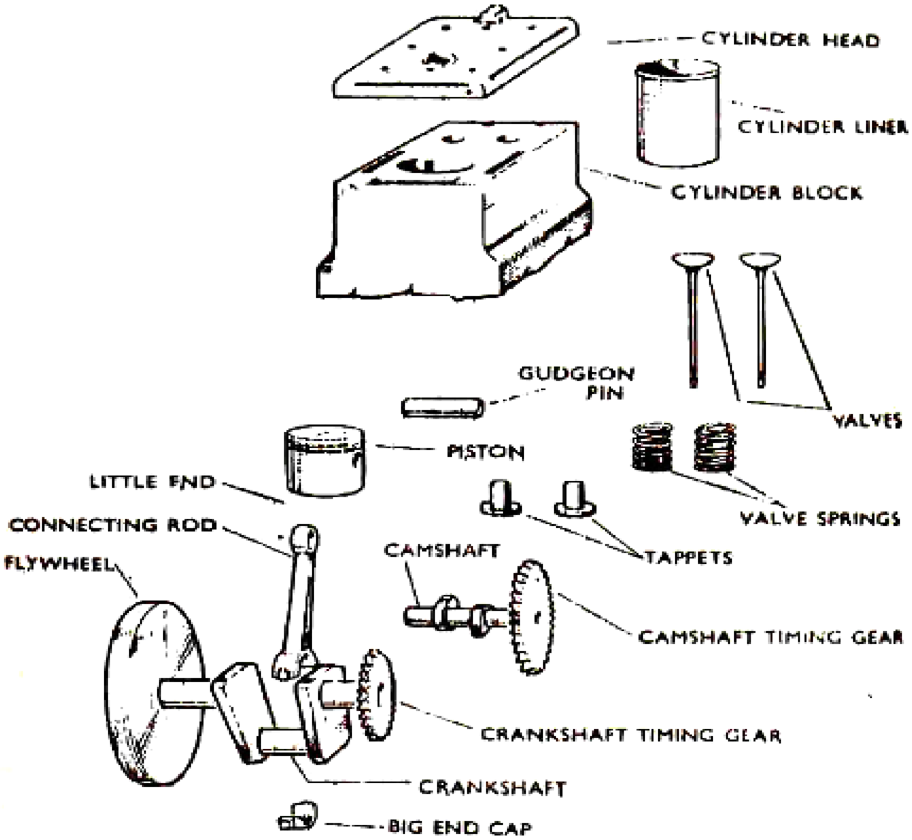
iv) Cylinder liner or sleeve: It is a cylindrical lining either wet or dry type which is inserted in the cylinder block in which the piston slides. Liners are classified as :
(1) Dry liner and (2) Wet liner.
Dry liner makes metal to metal contact with the cylinder block casing. Wet liners come in contact with the cooling water, whereas dry liners do not come in contact with the cooling water.

v) Piston: It is a cylindrical part closed at one end which maintains a close sliding fit in the engine cylinder. It is connected to the connecting rod by a piston pin. The force of the expanding gases against the closed end of the piston, forces the piston down in the cylinder. This causes the connecting rod to rotate the crankshaft (Fig 3). Cast iron is chosen due to its high compressive strength. Aluminium and its alloys preferred mainly due to it lightness.

Head (Crown) of piston: It is the top of the piston.
Skirt: It is that portion of the piston below the piston pin which is designed to absorb the side movements of the piston.

vi) Piston ring: It is a split expansion ring, placed in the groove of the piston. They are usually made of cast iron or pressed steel alloy (Fig.3). The function of the ring are as
follows :
a) It forms a gas tight combustion chamber for all positions of piston.
b) It reduces contact area between cylinder wall and piston wall preventing friction losses and excessive wear.
c) It controls the cylinder lubrication.
d) It transmits the heat away from the piston to the cylinder walls.
Piston rings are of two types: (1) Compression ring and (2) Oil ring

vii) Compression ring
Compression rings are usually plain, single piece and are always placed in the grooves of the piston nearest to the piston head. They prevent leakage of gases from the cylinder and helps increasing compression pressure inside the cylinder.
Oil ring: Oil rings are grooved or slotted and are located either in lowest groove above the piston pin or in a groove above the piston skirt. They control the distribution of lubrication oil in the cylinder and the piston.
Piston Pin: It is also called wrist pin or gudgeon pin. Piston pin is used to join the connecting rod to the piston.



viii) Connecting rod: It is special type of rod, one end of which is attached to the piston and the other end to the crankshaft (Fig.3). It transmits the power of combustion to the crankshaft and makes it rotate continuously. It is usually made of drop forged steel.

ix) Crankshaft: It is the main shaft of an engine which converts the reciprocating motion of the piston into rotary motion of the flywheel (Fig.3). Usually the crankshaft is made of drop forged steel or cast steel. The space that supports the crankshaft in the cylinder block is called *main journal*, whereas the part to which connecting rod is attached is known as *crank journal*. Crankshaft is provided with counter weights throughout its length to have counter balance of the unit.

x) Flywheel: Flywheel is made of cast iron. Its main functions are as follows :
a) It stores energy during power stroke and returns back the energy during the idle strokes, providing a uniform rotary motion of flywheel.
b) The rear surface of the flywheel serves as one of the pressure surfaces for the clutch plate.

c) Engine timing marks are usually stamped on the flywheel, which helps in adjusting the timing of the engine.
d) Sometime the flywheel serves the purpose of a pulley for transmitting power.

xi) Crankcase: The crankcase is that part of the engine which supports and encloses the crankshaft and camshaft. It provides a reservoir for the lubricating oil. It also serves as a mounting unit for such accessories as the oil pump, oil filter,, starting motor and ignition components. The upper portion of the crankcase is usually integral with cylinder block. The lower part of the crankcase is commonly called oil pan and is usually made of cast iron or cast aluminium

xii) Camshaft: It is a shaft which raises and lowers the inlet and exhaust valves at proper times. Camshaft is driven by crankshaft by means of gears, chains or sprockets (Fig3). The speed of the camshaft is exactly half the speed of the crankshaft in four stroke engine. Camshaft operates the ignition timing mechanism, lubricating oil pump and fuel pump. It is mounted in the crankcase, parallel to the crankshaft.

xiii) Timing gear: Timing gear is a combination of gears, one gear of which is mounted at one end of the camshaft and the other gear at the crankshaft. Camshaft gear is bigger in size than that of the crankshaft gear and it has twice as many teeth as that of the crankshaft gear. For this reason, this gear is commonly called half time gear. Timing gear controls the timing of ignition, timing of opening and closing of valve as well as fuel injection timing.

xiv) Inlet manifold: It is that part of the engine through which air or air-fuel mixture enters into the engine cylinder. It is fitted by the side of the cylinder head.

xv) Exhaust manifold: It is that part of the engine through which exhaust gases go out of the engine cylinder. It is capable of withstanding high temperature of burnt gases.
It is fitted by the side of the cylinder head.

xiv) Top dead centre - When the piston is at the top of its stroke, it is said to be at the
top dead centre (TDC),

xv) Bottom dead centre - when the piston is at the bottom of its stroke, it is said to be at its bottom dead centre (BDC).

Classification of steam engine [RGPV June06,Dec 06]

Basic classification of steam engine

(1) Cylinder arrangement

(A) Single cylinder
(B) Tandem
(C) Cross
(D) Duplex

(2) Longitudinal axis

(A) Vertical
(B) Inclined
(C) Horizontal

(3) Rotative speed

(A) High speed
(B) Medium speed
(C) Low speed

(4) Ratio of stroke to diameter

(A) Short stroke
(B) Long stroke

(4) Steam expansion

(A) Single expansion
(B) Multi-expansion

(5) Steam flow

(A) Counter flow
(B) Uniflow

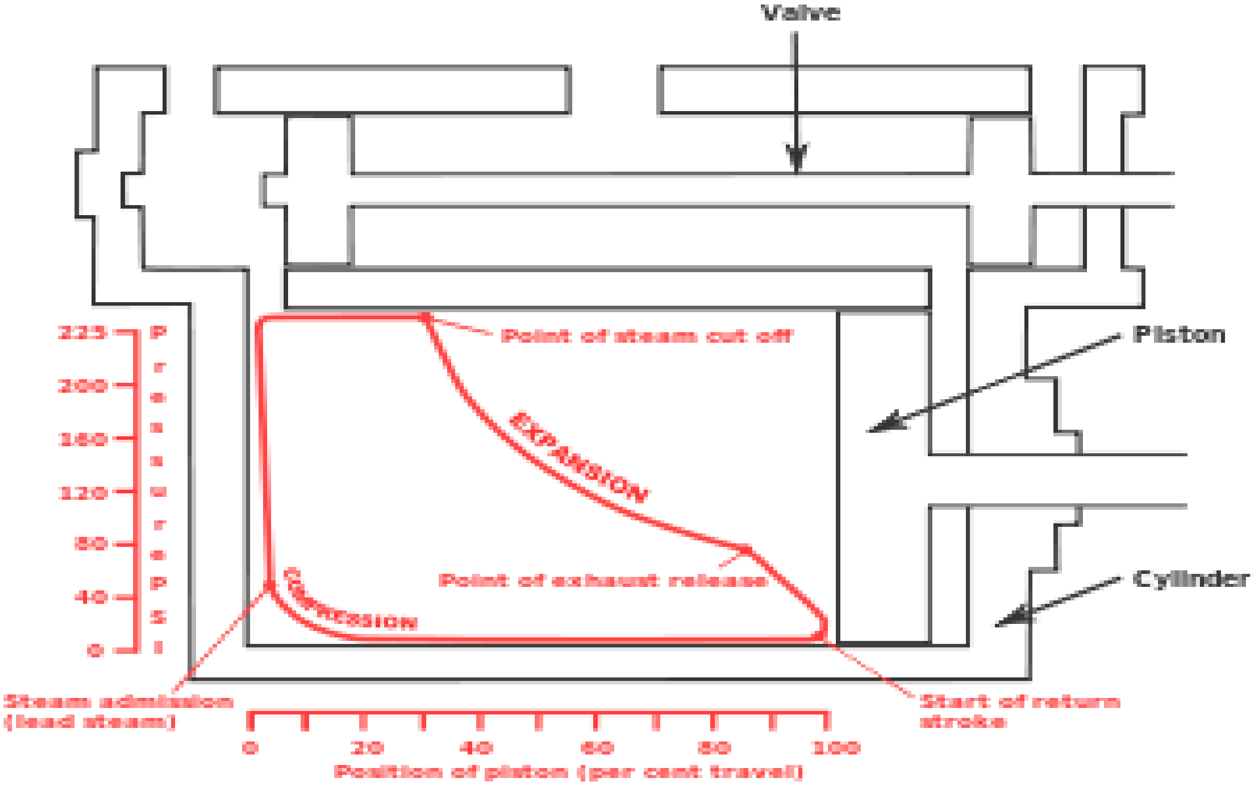
(6) Use

(A) Stationary engines
(B) Portable engines

(C) Locomotive engines
(D) Marine engines
(E) Hoisting engines

Reciprocating piston(Double acting stationary engine)

Double acting stationary engine. The slide valve with concave, almost "D" shaped, underside.



Indicator diagram showing the four events in a double piston stroke. See: Monitoring and control (above)
Main article: Reciprocating engine

In most reciprocating piston engines, the steam reverses its direction of flow at each stroke (counter flow), entering and exhausting from the cylinder by the same port. The complete engine cycle occupies one rotation of the crank and two piston strokes; the cycle also comprises four *events* – admission, expansion, exhaust, compression. These events are controlled by valves often working inside a *steam chest* adjacent to the cylinder; the valves distribute the steam by opening and closing steam *ports* communicating with the cylinder end(s) and are driven by valve gear, of which there are many types.The simplest valve gears give events of fixed length during the engine cycle and often make the engine rotate in only one direction. Most however have a reversing mechanism which additionally can provide means for saving steam as speed and momentum are gained by gradually "shortening the cutoff" or rather, shortening the admission event; this in turn proportionately lengthens the expansion period. However, as one and the same valve usually controls both steam flows, a short cutoff at admission adversely affects the exhaust and compression periods which should ideally always be kept fairly constant; if the exhaust event is too brief, the totality of the exhaust steam cannot evacuate the cylinder, choking it and giving excessive compression (*"kick back"*).

Component of steam engine.

The Firebox

The firebox is the compartment in the locomotive which houses the fire. It is designed to burn fuel, usually coal, efficiently and to produce sufficient heat to boil water and create steam. Fireboxes consist of two enclosures, the outer firebox and the inner firebox. The former is usually made of steel while the latter is either made of copper or steel. They are connected by stays, which are bolts that keep the inner firebox rigid within the outer firebox.

The Boiler

The boiler is the enclosure on a locomotive where steam is produced. It must be filled with water almost to the top. Hot gases from the boiler pass through hollow tubes running the length of the boiler, thus heating the water. When the water boils, the steam it generates forms in the space between the top of the water and the top of the boiler. Steam will tend to rise to the highest point, which is the steam dome. The amount of steam in the steam dome released to the main steam pipe is controlled by the regulator valve. If more power is needed, more steam is released.

The Regulator

Once the boiler has generated sufficient steam, it can be used for useful work. A lever is used to control the amount of steam entering the locomotive cylinders. This lever is called the regulator. A regulator valve fitted on top of the boiler and housed in the dome is opened and closed by means of a long shaft connected to a lever accessed from the driver's position in the locomotive cab. The shaft passes through the boiler steam space.

Superheating

The steam generated in a boiler is called saturated steam because it is in contact with water. Using the pressure of saturated steam to move the pistons in the cylinder is very inefficient since water will be condensed during the expansion. Condensed steam produces little power.

The Cylinders, Pistons and Cylinder Valves

A steam locomotive usually has two, three of four cylinders depending on the design and power requirements. Next to each cylinder is the steam chest containing a valve which controls the flow of steam into and out from the cylinder. A cylinder typically has a port at each end and the valve covers and uncovers these ports so that at one time one port acts as the admission port while the other as the exhaustion port. The fresh steam from the boiler stores a large amount of energy and tends to expand immediately after being injected into the cylinder. The energy from the high pressure steam is converted into mechanical work by pushing against the piston in the cylinder.

The Blast pipe

The pipe which carries the exhaust steam from the cylinders to the centre of the smokebox is called the blast pipe. It is vertical and placed at the bottom of the smokebox facing the chimney exit. Other then letting exhaust steam to pass through, the smokebox also draws gases from the firebox to exit through the chimney.

Study with AKASH

If you have any queries please visit- https://studywithakash.in/

Gmail – studywithakash311@gmail.com

+918871317984

THANK YOU