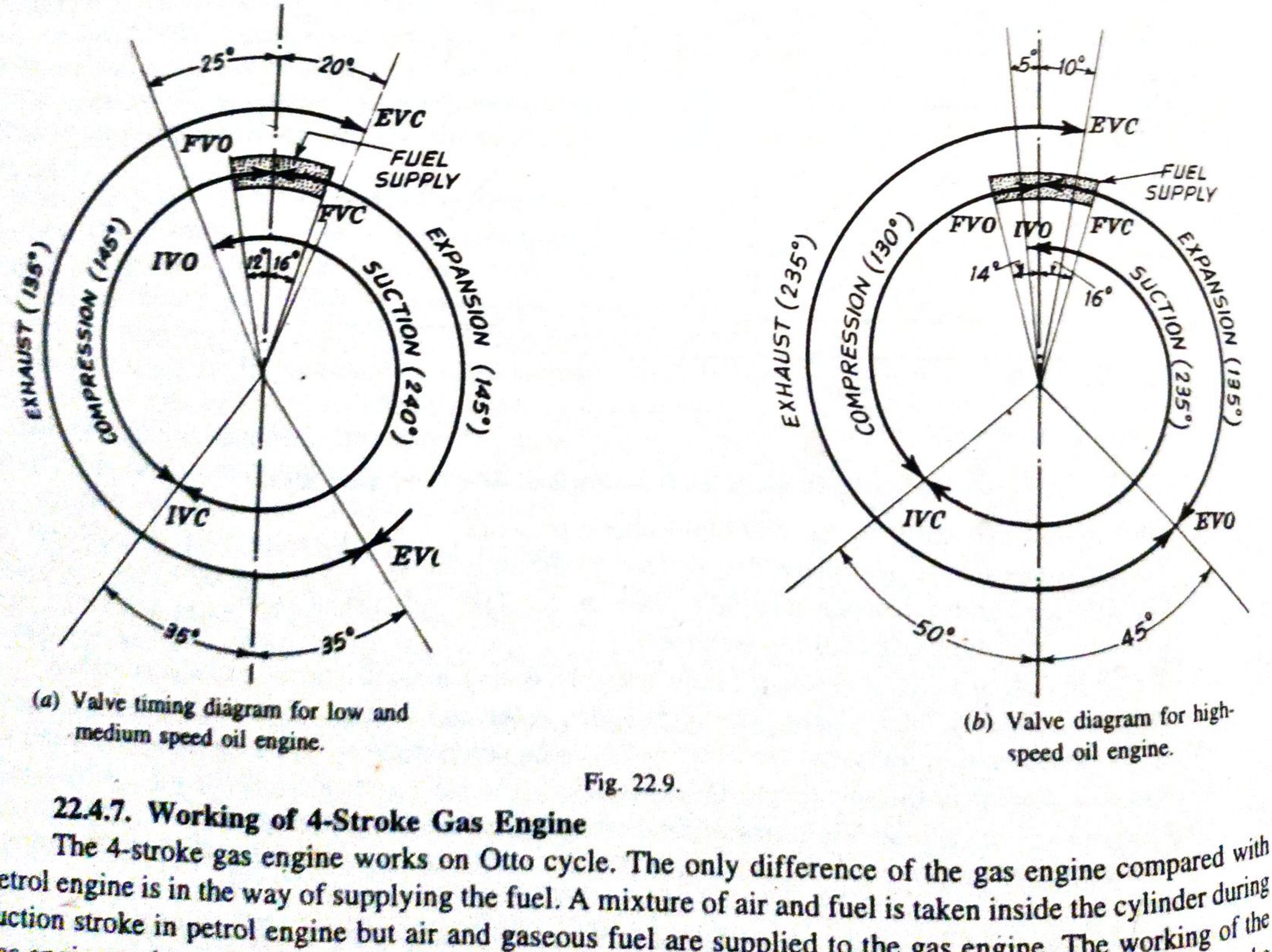
22.4.6. Valve Timing Diagram for 4-Stroke Diesel Engine

The actual valve timing diagram is different from the theoretical diagram for the same reasons as discussed in the case of petrol engine.

The actual valve timing diagrams for low and high speed diesel engines are shown in Figs. 22.9 (*a*) and 22.9 (*b*).

The opening of the fuel valve before TDC is necessary for better evaporation and mixing of the fuel. As there is always lag between ignition and supply of fuel, it is always necessary to supply the fuel little earlier.

Comparing Fig. 22.6 (*a*) for 4-stroke petrol engine, and Fig. 22.9 (*a*) for 4-stroke diesel engine, it is obvious that the overlapping provided for diesel engine (45°) is sufficiently large compared with the petrol engine (13°). More overlapping is not adviseable in petrol engine because the mixture of air and petrol may pass out with the exhaust gases and it is highly uneconomical. This danger does not arise in case of diesel engine because only air is taken during the suction stroke.



(*a*) Valve timing diagram for low and medium speed oil engine.

(*b*) Valve diagram for high-speed oil engine.

Fig. 22.9.

22.4.7. Working of 4-Stroke Gas Engine

The 4-stroke gas engine works on Otto cycle. The only difference of the gas engine compared with petrol engine is in the way of supplying the fuel. A mixture of air and fuel is taken inside the cylinder during suction stroke in petrol engine but air and gaseous fuel are supplied to the gas engine. The working of the gas engine and *p-v* diagram is exactly similar to the petrol engine. The valve timing diagram for 4-stroke gas engine is also exactly similar to the 4-stroke petrol engine except the supply of gas. The positions of the opening and closing of gas valve superimposed on valve timing diagram of 4-stroke petrol engine as shown in Fig. 22.10.

The crank rotation allowed for the opening of gas valve is sufficiently large compared with diesel engine and that is because the density and calorific value of the gas are considerably less than that of diesel oil.

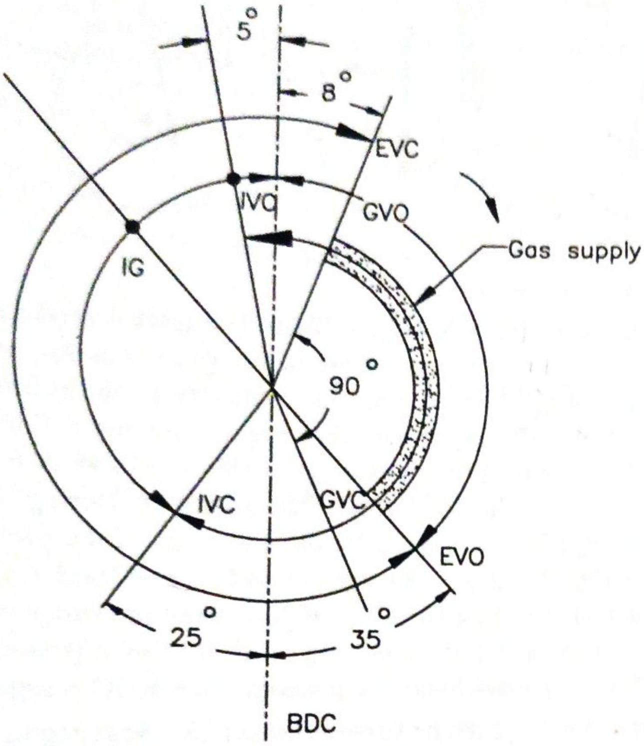


Fig. 22.10. Valve timing diagram for 4-stroke gas engine.

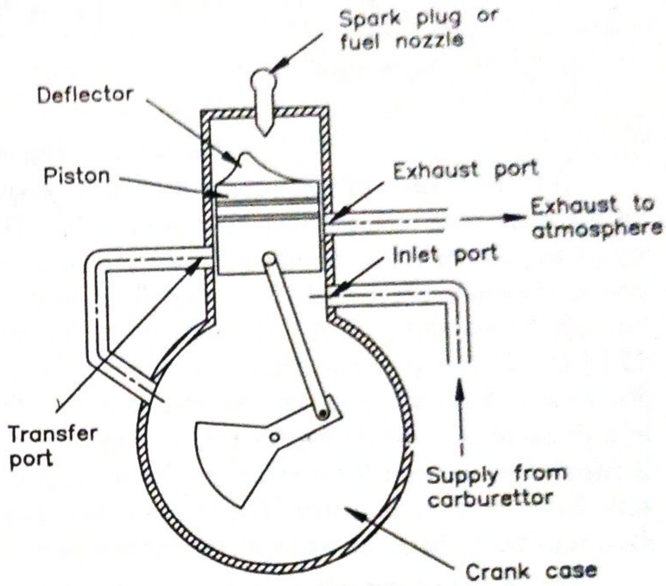


Fig. 22.11. Two-stroke petrol engine.

22.5. TWO-STROKE ENGINES

In this engine, the working cycle is completed in two strokes of the piston or one revolution of the crank shaft instead of 4-strokes or two revolutions of crankshaft as in case of 4-stroke engine.

In case of two strokes engine, the valves are replaced by the ports. Two rows of the ports at different levels are cut in the cylinder walls as shown in Fig. 22.11. These are known as Exhaust ports and transfer ports. In the case of single cylinder engines, a third row of ports is provided below the first two and these are known as inlet ports.

A specific shape is given to the piston crown as shown in Fig. 22.11 which helps to prevent the loss of incoming fresh charge being short-circuited through the transfer ports and helps for exhausting only the burnt gases.

The charging of the cylinder with air-fuel mixture in case of petrol engine or with air in case of diesel engine, compression of mixture of air, expansion of gases and exhausting of burnt gases from the cylinder are carried out in two strokes. This can be done by using the following two methods.

1. By using the closed crank-case compression. In this method, the crank case works as an air-pump as the piston moves up and down. The charge or air to be admitted in the cylinder is compressed in the crank-case by the pumping action of the underside of the piston as shown in Fig. 22.11. This system is known as three channel system and commonly used for single cylinder small power engines as scooter and motor-cycle engines.

2. A separate pump outside the cylinder is provided to compress the charge or air before forcing it into the cylinder. The pump is an integral part of the engine and it is driven by the engine itself. This method of charging is used for large capacity multicylinder engines.

22.5.1. Working of Two Stroke-petrol Engine

It will be easier to describe the cycle beginning at the point when the piston has reached to TDC completing the compression stroke.

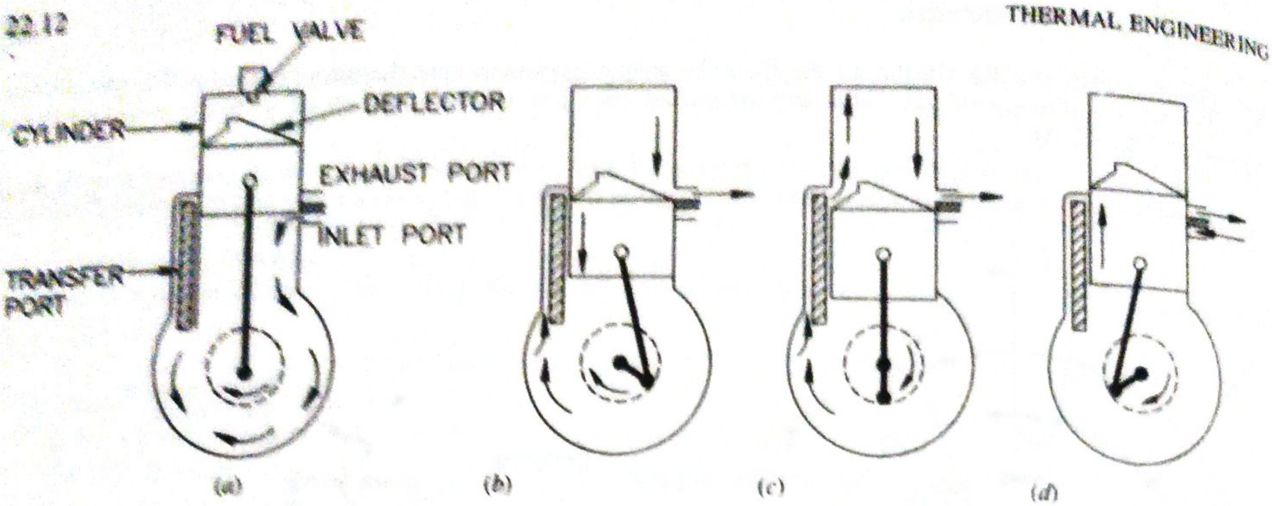


Fig. 22.12. Working of 2-stroke petrol engine.

(*a*) The position of the piston at the end of compression is shown in Fig. 22.12 (*a*). The spark is produced by the spark plug as the piston reaches the TDC. The pressure and temperature of the gases increase and the gases push the piston downward producing the power stroke. When the piston uncovers (opens) the exhaust port as shown in Fig. 22.12 (*b*) during the downward stroke, the expanded burnt gases leave the cylinder through the exhaust port. A little later, the piston uncovers (opens) the transfer ports also as shown in Fig. 22.12 (*c*). In this position, the crank-case is directly connected to the cylinder through port. During the downward stroke of the piston, the charge in the crank-case is compressed by the underside of the piston to a pressure of 1.4 bar. At this position, as shown in Fig. 22.12 (*c*), the compressed charge (fuel + air) is transferred through the transfer port to the upper part of the cylinder. The exhaust gases are swept out with the help of fresh charge. The piston crown shape helps in this sweeping action as well as it prevents the loss of fresh charge carried with the exhaust gases. This is continued until the piston reaches BDC position.

This action of sweeping out the exhaust gases with the help of fresh charge is known as "Scavenging". The scavenging helps to remove the burnt gases from the cylinder. During this stroke of the piston (downward stroke) the following processes are completed.

(*a*) Power is developed by the downward movement of the piston caused by the high pressure gases.

(*b*) The exhaust gases are removed completely from the cylinder by scavenging.

(*c*) The charge is compressed in the crank-case with the help of underside of the piston.

As the piston moves upward, it covers the transfer ports stopping the flow of fresh-charge into the cylinder. A little later, the piston covers the exhaust ports and actual compression of the charge begins. This position of the piston is shown in Fig. 22.12 (*d*). The upward motion of the piston during this stroke lowers the pressure in the crank case below atmosphere, therefore, a fresh charge is induced in the crank case through the inlet ports as they are uncovered by the piston.

The compression of the charge is continued until the piston reaches to its original position (TDC) and the cycle is completed as shown in Fig. 22.12 (*a*).

In this stroke of the piston, the following processes are completed.

1. Partly scavenging takes place as the piston moves from BDC to the position shown in Fig. 22.12 (*c*).
2. The fresh charge is sucked in the crankcase through the carburettor.
3. Compression of the charge is completed as the piston moves from the position shown in Fig. 22.12 (*c*) to TDC as shown in Fig. 22.12 (*a*).

The cycle of the engine is completed within two strokes of the piston.

22.5.2. Theoretical and Actual p-v. Diagram for 2-stroke Petrol Engine

The following assumptions are made during the operating cycle of the two-stroke petrol engine.

1. Expansion during power stroke and compression during compression stroke are isentropic.
2. The combustion takes place instantaneously at constant volume at the end of compression.

3. The pressure falls instantaneously to the atmospheric pressure as the piston uncovers the exhaust ports during downward (power) stroke.

4. The scavenging (taking the charge into the cylinder and sweeping out exhaust gases to the atmosphere) takes place at atmospheric pressure.

The working of the cycle can be represented on p-v diagram as shown in Fig. 22.13 (a) and it is similar to theoretical Otto-cycle.

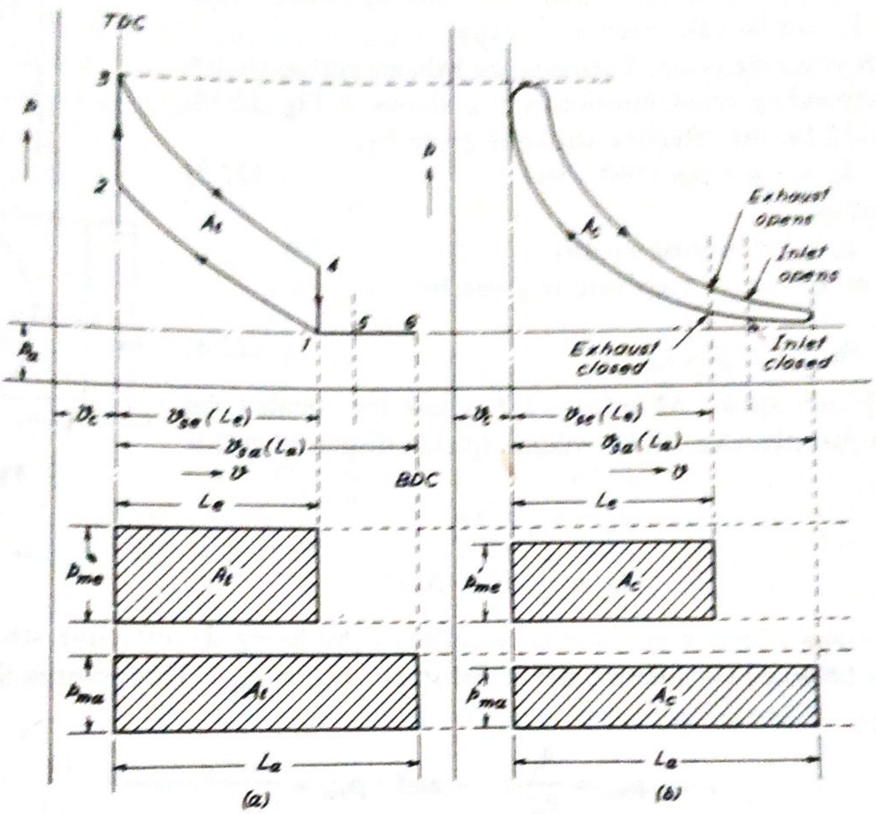


Fig. 22.13. Theoretical and Actual p-v diagrams for 2-stroke petrol engine.

where p_{me} = Theoretical mean effective pressure on the basis of effective stroke

p_{me}' = Actual mean effective pressure on the basis of effective stroke.

p_{ma} = Theoretical mean effective pressure on the basis of actual stroke.

p_{ma}' = Actual mean effective pressure on the basis of actual stroke.

1-2 → Isentropic compression

2-3 → Instantaneous combustion at constant volume

3-4 → Isentropic expansion

4-1 → Release to atmospheric pressure as the exhaust ports open.

1-6 and 6-1 → Sweeping out the exhaust gases to atmosphere.

The point '5' indicates the opening of the inlet or transfer ports.

5-6 and 6-5 → Charging the cylinder with fresh charge through the transfer ports and scavenging action takes place.

It is obvious from Fig. 22.13 (a), that the compression of the charge starts from point '1' instead of point '6', therefore, the effective stroke (compression stroke or actual compression ratio) is less than the actual stroke.

The effective compression ratio is given by

$$R_{ce} = \frac{v_{se} + v_c}{v_c} \quad \text{... (22.1)}$$

where v_{se} is the effective stroke volume and v_{sa} is the actual stroke volume. The effective stroke volume is given by

$$v_{se} = \frac{\pi}{4} d^2 \times L_e \quad \text{... (22.2)}$$

where d is the diameter of the cylinder and L_e is the effective stroke of the engine.

If the exhaust ports open 'θ' degrees after TDC (during power stroke or down-stroke). Then L_e can be calculated as follows.

When the piston reaches the point of opening the exhaust port as shown in Fig. 22.14, the corresponding crank position is also shown in Fig. 22.14.

Referring to Fig. 22.14, the effective stroke is given by,

$$L_e = r + r\cos(180 - \theta) \quad \text{... (22.3)}$$

where r is the crank-radius

$$L_a = 2r \text{ (Actual stroke).}$$

The air standard efficiency of the cycle is given by

$$\eta_a = 1 - \frac{1}{R_{ce}^{\gamma - 1}} \quad \text{... (22.4)}$$

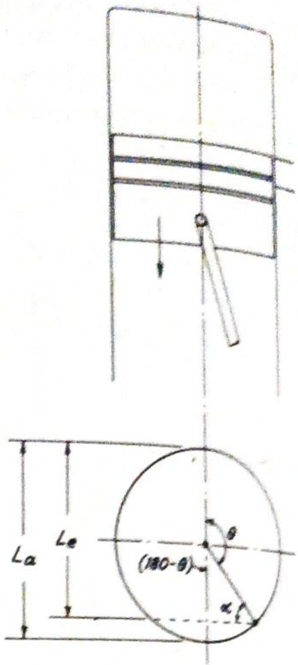


Fig. 22.14.

The part of the piston stroke $\Delta L = (L_a - L_e)$ is lost for opening the exhaust ports, therefore the effective stroke volume (piston displacement) is given by

$$v_{se} = v_{sa} - \Delta v \quad \text{... (22.5)}$$

where

$$\Delta v = \frac{\pi}{4} d^2 \times (\Delta L).$$

If the theoretical mean effective pressure is calculated considering the effective stroke then it gives higher value than that is obtained considering the actual stroke ($p_{me} > p_{ma}$). This point is illustrated in Fig. 22.13 (a).

$$p_{me} = \frac{A_t}{v_{se}}; \quad \text{and} \quad p_{ma} = \frac{A_t}{v_{sa}}$$

$$\therefore \quad p_{me} = p_{ma} \cdot \frac{v_{sa}}{v_{se}} = p_{ma} \cdot \frac{L_a}{L_e}$$

$$= p_{ma} \cdot \frac{L_a}{L_a - \Delta L} = p_{ma} \cdot \frac{1}{1 - \frac{\Delta L}{L_a}} = p_{ma}\left(\frac{1}{1 - \phi}\right) \quad \text{... (22.6)}$$

where $\phi = \frac{\Delta L}{L_a}$ is the % part of the piston stroke corresponding to the height of the exhaust ports.

In the design of the two-stroke engine, it is always preferable to consider the mean effective pressure on the basis of actual stroke.

In the above operations, all the ideal conditions are assumed but in practice, the actual conditions differ from the ideal as described below :

1. The compression and expansion do not follow the isentropic law.

2. Instantaneous combustion at the end of compression is not possible. Therefore, actual pressure rise is less than theoretical. The pressure increase takes place through some crank rotation therefore rounding of the diagram takes place.

3. The scavenging (charging the cylinder with fresh charge and sweeping out the exhaust gases to the atmosphere) always takes place above atmosphere pressure and therefore the pressure inside the cylinder never falls below atmosphere like four-stroke engine.

4. Instantaneous fall of pressure at the time of release is not possible.
5. There are friction losses during all operations considered.

If all these modifications are taken into account then the cycle can be represented on *p-v* diagram introducing all above mentioned modifications

22.5.3 V