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LECTURE NOTES

BASIC MECHANICAL ENGINEERING

(BT-203)

Year : I Semester : I/II

UNIT-V

RECIPROCATING MACHINES

Part 2-Four Stroke Petrol Engines

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CHAPTER NO. 2

Working of 4 Stroke Petrol Engines

2.1 INTRODUCTION

All operations are carried out in four strokes of the piston, i.e., two revolutions of the crank shaft. Therefore, the engine is called a four-stroke engine. A large number of internal combustion engines, both petrol and diesel, operate on a four-stroke cycle.

2.2 CONSTRUCTIONAL DETAILS

Petrol engine (spark ignition engine) consist of a cylinder, cylinder head attached with spark plug, piston attached with piston ring, connecting rod, crank, crank shaft, etc., as shown in Fig. 2.1. In a four-stroke engine, valves are used instead of ports. There are inlet and exhaust valves. These valves are operated by cams attached on a separate shaft, called a cam shaft. It is rotated at half the speed of a crank shaft.

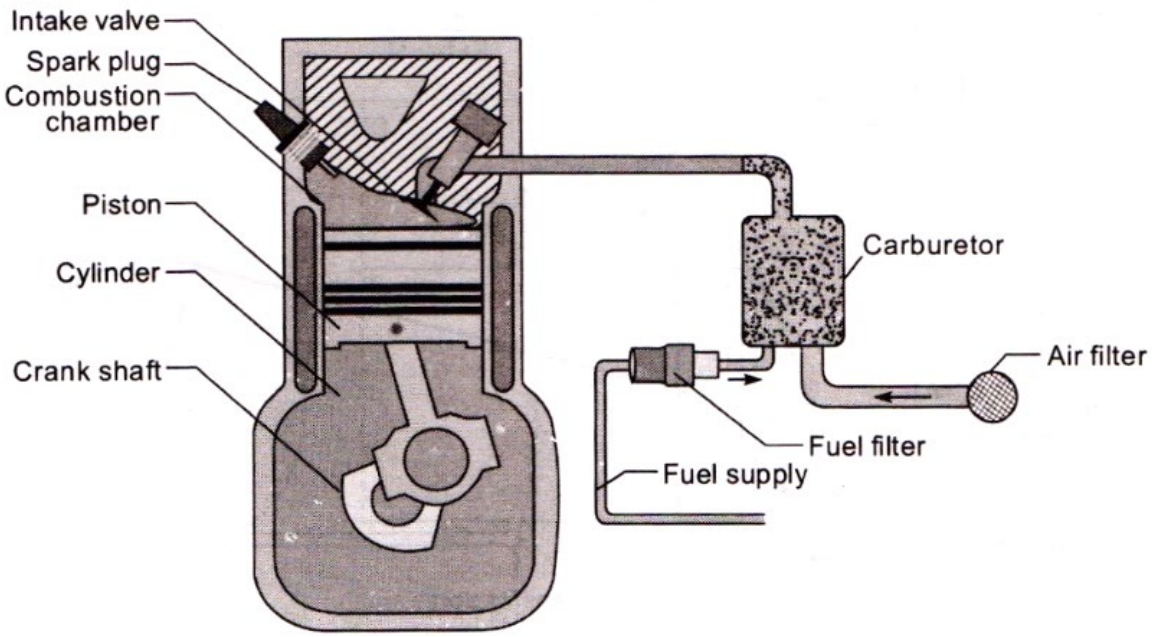


Figure 2.1 Four Stroke Petrol Engine

2.3 OPERATIONS

The travel of the piston from one dead centre to another is called piston stroke and a four-stroke cycle consists of four strokes as suction, compression, expansion and exhaust strokes. The sequence of four strokes is as follows: -

1. Intake or suction stroke,
2. Compression stroke,
3. Working or expansion or power stroke and,
4. Exhaust stroke.

1. **Suction Stroke** Suppose that the piston is very near to the top dead centre position (T.D.C.) [Fig 2.2 (a)]. During suction stroke the inlet valve is opened and the discharge valve is closed and the piston moves down (i.e. outward) due to rotation of the crankshaft either getting energy from the flywheel or a motor starter. As the piston move, vacuum is created between the piston and cylinder and the pressure in the cylinder drops below atmospheric pressure. The piston moves from the top dead centre to the bottom dead centre, the charge (mixture of fuel and air prepared in the carburettor) rushes inside the cylinder through inlet manifold and valve which is cam operated. The suction process continues till the piston reaches the bottom dead centre position (B.D.C.).

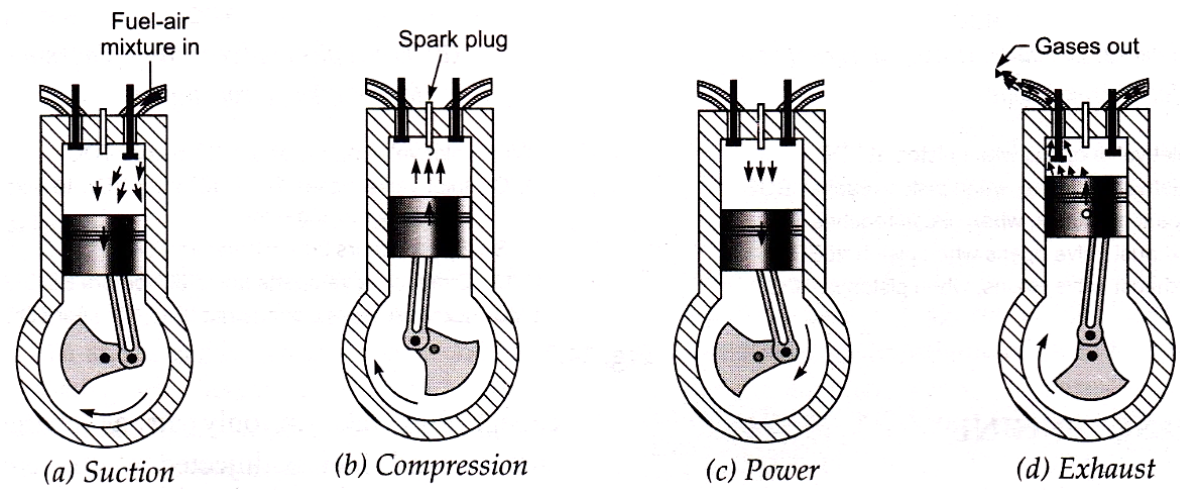


Figure 2.2 Operations of a Four Stroke Petrol Engine

2. **Compression Stroke** During a compression stroke [Fig 2.2 (b)], both the valves are closed and the piston moves from bottom to top dead centre position. The charge or air is compressed up to a compression ratio which depends upon the type and need of the engine. Since both the valves are closed and the piston moves inwards, there is a reduction in volume of the charge which results in an increase of pressure and temperate of the cylinder contents. In petrol engines, the compression ratio varies from 6 to 12 and pressure and temperature at the end of compression are 7 to 14 bar and 250°C to 300°C respectively.

3. **Expansion Stroke** During power stroke [Fig 2.2 (c)], both the valves are closed. The power stroke includes combustion of fuel and expansion of the products of combustion. The combustion starts at the end of the compression stroke when the piston is approaching the T.D.C. position. In S.I. Engine a spark plug initiates the combustion. During combustion the chemical energy of the fuel is released and there is a rise in temperature and pressure of the gas. The temperature of the gases is increased to between 1800-2300°C and the pressure to 30–40 bar. The volume of the gas however remains constant during combustion. The high pressure and the high temperature of the products of combustion, thus obtained, pushes the piston outward from T.D.C. to B.D.C. position for expansion stroke. This reciprocating motion of the piston is converted into rotary motion by the crankshaft, connecting rod and crank mechanism.

4. **Exhaust Stroke** During this stroke, the piston moves from the bottom dead centre to the top dead centre, exhaust valve opens and the inlet valve remains closed [Fig 2.2 (d)]. Burnt gases of the previous stroke are expelled out from the cylinder by upward movement of the piston. At the end of the power stroke the pressure of the gas is about 4-5 bar which is higher than the exhaust manifold pressure.

At the end of the exhaust stroke the inlet valve opens, and the cylinder is ready to receive the fresh charge to begin a new cycle.

It is obvious from the above discussions that the crankshaft makes two revolutions during the four strokes, and in these four strokes, there is only one power stroke. This means, that for every two revelations of the crankshaft, there is only one power strike.

2.4 THEORETICAL INDICATOR DIAGRAM (P-V DIAGRAM)

In the above operation, the following assumption were made-

(i) Suction and exhaust take place at atmospheric pressure.

(ii) Suction and exhaust take place at 180o rotation of crank.

(iii) Compression and expansion also take place at 180o rotation of crank.

(iv) Compression and expansion are isentropic.

(v) The combustion takes place instantaneously at constant volume at the end of compression stroke.

(vi) Pressure suddenly falls to the atmospheric pressure at end of expansion stroke.

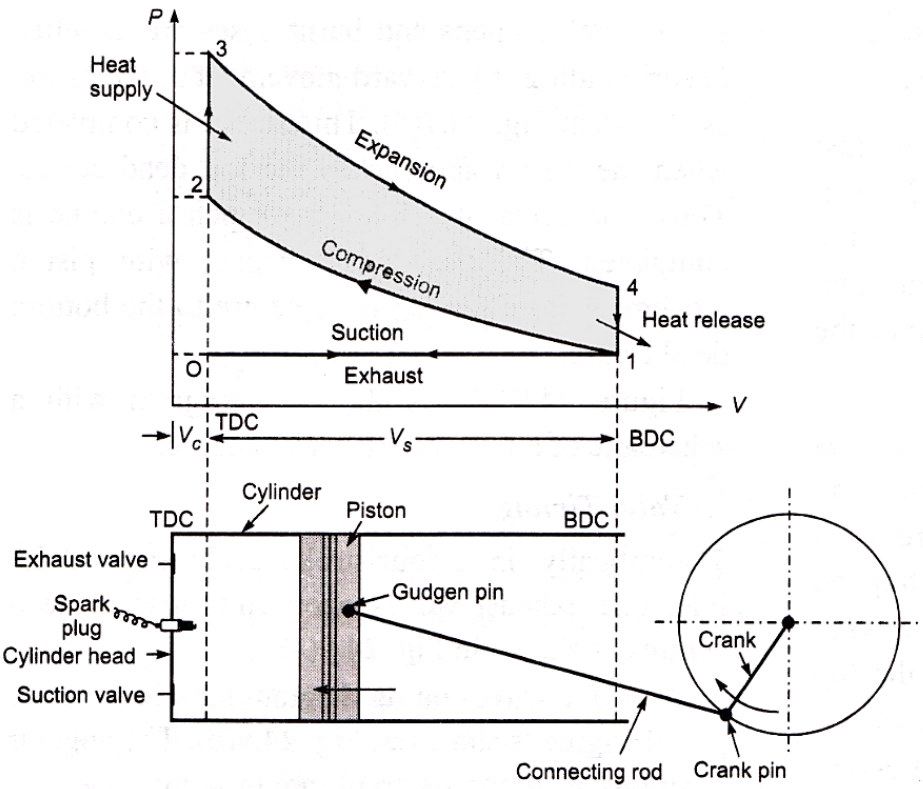


Figure 2.3 Theoretical indicator diagram (P-V Diagram) of a Four Stroke Petrol Engine

With these assumptions the working of 4-Stroke Otto cycle engine on p-V diagram as shown in Fig. 2.3.

Process 0-1 (Suction Stroke): In this process fresh air and fuel mixture i.e., charge is passed inside the cylinder. The piston moves from top dead centre to bottom dead centre. This comprises the first stroke of the engine.

Process 1-2 (Compression Stroke): In this process the charge is compressed and piston is moved to top dead centre. This comprises the second stroke of the engine.

Process 2-3 (Instantaneous-Combustion): In this process spark plug ignites the spark and the fuel is burnt. This process is of constant volume and increase in pressure.

Process 3-4 (Expansion Stroke): In this process the burnt fuel expands itself and exerts pressure on the piston. The piston moves from top dead centre to bottom dead centre. This comprises the third stroke of the engine and the power stroke.

Process 4-1(Sudden Fall in Pressure): In this process the burnt gas is exhausted out and the pressure decreases with constant volume.

Process 1-0 (Exhaust Stroke): In this process the burnt gas is completely moved out of the cylinder by the action of piston. Piston moves from bottom dead centre to top dead centre. This comprises the fourth stroke of the engine.

2.5 ACTUAL INDICATOR DIAGRAM

In the theoretical indicator diagram, all the ideal conditions are assumed but in practice, the actual conditions differ from the ideal as described below (Fig. 2.4.).

(i) The suction of mixture in the cylinder is possible only if the pressure inside the cylinder is below atmospheric pressure.

(ii) The burnt gases can be pushed out into the atmosphere only if the pressure of the exhaust gases is above atmospheric pressure.

(iii) The combustion and expansion do not follow the isentropic law, as there will be heat exchange during process.

(iv) Sudden pressure rise is not possible after ignition as combustion take sometimes for completion and actual pressure rise is less than theoretical considered. The pressure increase takes place through some crank rotation, or increase in volume.

(v) Sudden pressure release after the opening of expansion valve is not possible and also takes place through some crank rotation.

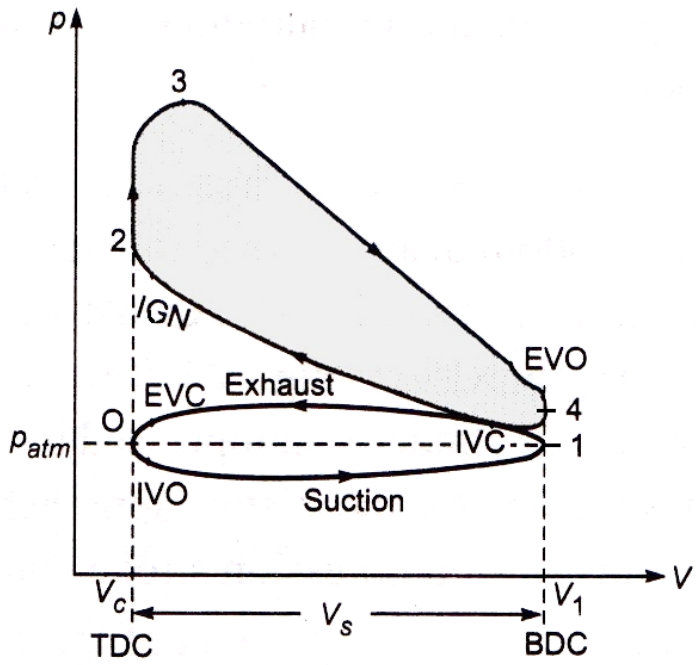


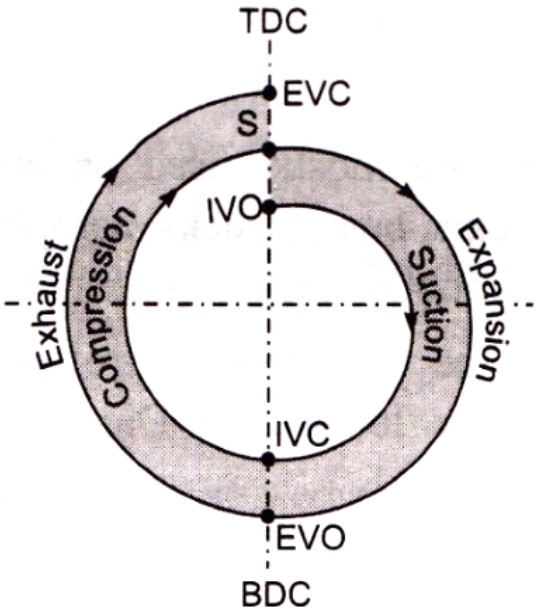
Figure 2.4 Actual indicator diagram (P-V Diagram) of a Four Stroke Petrol Engine

The suction stroke by the line 0-1, which lies below the atmospheric pressure line. It is this pressure difference, which makes the fuel air mixture to flow into the engine cylinder. The inlet valve offers some resistance to the incoming charge. That is why, the charge cannot enter suddenly into the engine cylinder. As a result of this, pressure inside the cylinder remains somewhat below the atmospheric pressure during the suction stroke. The compression stroke is shown by the line 1-2, which shows that the inlet valve close (I.V.C) a little beyond 1 (i.e. BDC). At the end of this stroke, there is an increase in the pressure inside the engine cylinder. Shortly before the end of compression stroke (i.e. TDC). the

charge is ignited (IGN) with the help of spark plug as shown in the figure. The sparking suddenly increases pressure and temperature of the products of combustion. But the valve practically, remains constant as shown by the line 2-3. The expansion stroke is shown by the line 3-4, in which the exit valve opens (EVO) a little before 4 (i.e. B.D.C). Now the burnt gases are exhausted into the atmosphere through the exit valve. The exhaust stroke is shown by the line 4-0, which lies above the atmospheric pressure line. It is this pressure difference, which makes the burnt gases to flow out of the engine cylinder. As a result of this. pressure inside the cylinder remains somewhat above the atmospheric pressure line during the exhaust stroke.

2.6 VALVE TIMING DIAGRAM

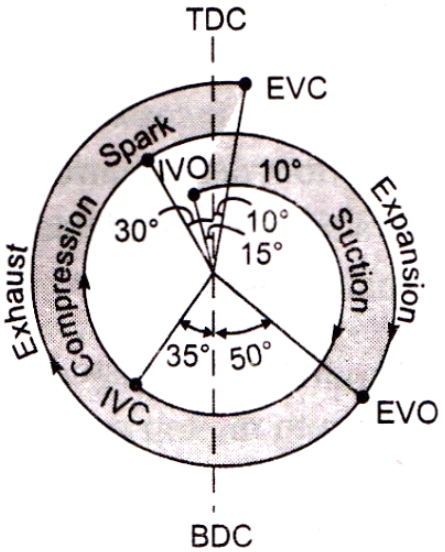
Theoretically, in a four-stroke cycle engine, the inlet and exhaust valves open and close at dead centres as shown in Fig. 2.5.



IVO = Inlet valve opens when piston at TDC
IVC = Inlet valve closes, when piston reaches BDC
S = Spark produces, when piston reaches TDC
EVO = Exhaust valve opens when piston at BDC
EVC = Exhaust valve closes, when piston at TDC

Figure 2.5 Theoretical Valve-Timing Diagram for Four-stroke cycle engine

A typical actual valve-timing diagram for a four-stroke petrol engine is shown in Fig. 2.6. The angular positions in terms of crank angle with respect to TDC and BDC position of piston are quoted on the diagram. When the inlet valve and exhaust valve remain open simultaneously, it is called a valve overlap.



IVO : Inlet valve opens about 15° before TDC
IVC : Inlet valve closes 20° – 40° after BDC to take advantage of rapidly moving gas
S : Spark occurs 20°–40° before TDC
EVO : Exhaust valve opens about 50° before BDC
EVC : Exhaust valve close about 0° to 10° after TDC

Figure 2.6 Actual Valve-Timing Diagram for Four-Stroke Petrol Engine

2.7 APPLICATIONS

These engines are mostly used on automobiles, motor cycles, cars, buses, trucks, aeroplanes, small pumping sets, mobile electric generators, etc. Nowadays, the four-stroke petrol engines have been replaced by four-stroke Diesel engines for most applications.

QUESTIONS FOR EXAMINATION

Q.1. Explain working of 4-Stroke Petrol/SI engines.

Ans. See Section 2.3.

Q.2. Draw and explain theoretical indicator diagram for 4-Stroke Petrol/SI engines.

Ans. See Section 2.4.

Q.3. Draw and explain actual indicator diagram for 4-Stroke Petrol/SI engines.

Ans. See Section 2.5.

Q.4. Draw theoretical valve timing diagram for 4-Stroke Petrol/SI engines.

Ans. See Section 2.6.

Q.5. Draw actual valve timing diagram for 4-Stroke Petrol/SI engines.

Ans. See Section 2.6.

Q.6. State various applications of 4-Stroke S.I./Petrol engine.

Ans. See section 2.7