INTERNAL COMBUSTION ENGINE

INTRODUCTION

Heat engine:

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. It is classified into two types-

(a) External combustion engine
(b) Internal combustion engine

External combustion engine:

In this engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle.

Examples:

*In the steam engine or a steam turbine plant, the heat of combustion is employed to generate steam which is used in a piston engine (reciprocating type engine) or a turbine (rotary type engine) for useful work.

*In a closed cycle gas turbine, the heat of combustion in an external furnace is transferred to gas, usually air which the working fluid of the cycle.

Internal combustion engine:

In this engine, the combustion of air and fuels take place inside the cylinder and are used as the direct motive force. It can be classified into the following types:

1. According to the basic engine design- (a) Reciprocating engine (Use of cylinder piston arrangement), (b) Rotary engine (Use of turbine)
2. According to the type of fuel used- (a) Petrol engine, (b) diesel engine, (c) gas engine (CNG, LPG), (d) Alcohol engine (ethanol, methanol etc)
3. According to the number of strokes per cycle- (a) Four stroke and (b) Two stroke engine
4. According to the method of igniting the fuel- (a) Spark ignition engine, (b) compression ignition engine and (c) hot spot ignition engine
5. According to the working cycle- (a) Otto cycle (constant volume cycle) engine, (b) diesel cycle (constant pressure cycle) engine, (c) dual combustion cycle (semi diesel cycle) engine.
6. According to the fuel supply and mixture preparation- (a) Carburetted type (fuel supplied through the carburettor), (b) Injection type (fuel injected into inlet ports or inlet manifold, fuel injected into the cylinder just before ignition).

7. According to the number of cylinder- (a) Single cylinder and (b) multi-cylinder engine

8. Method of cooling- water cooled or air cooled

9. Speed of the engine- Slow speed, medium speed and high speed engine

10. Cylinder arrangement- Vertical, horizontal, inline, V-type, radial, opposed cylinder or piston engines.

11. Valve or port design and location- Overhead (I head), side valve (L head); in two stroke engines: cross scavenging, loop scavenging, uniflow scavenging.

12. Method governing- Hit and miss governed engines, quantitatively governed engines and qualitatively governed engine


Main components of reciprocating IC engines:

**Cylinder:** It is the main part of the engine inside which piston reciprocates to and fro. It should have high strength to withstand high pressure above 50 bar and temperature above 2000 °C. The ordinary engine is made of cast iron and heavy duty engines are made of steel alloys or aluminum alloys. In the multi-cylinder engine, the cylinders are cast in one block known as cylinder block.

**Cylinder head:** The top end of the cylinder is covered by cylinder head over which inlet and exhaust valve, spark plug or injectors are mounted. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an air tight joint.

**Piston:** Transmit the force exerted by the burning of charge to the connecting rod. Usually made of aluminium alloy which has good heat conducting property and greater strength at higher temperature.

**Piston rings:** These are housed in the circumferential grooves provided on the outer surface of the piston and made of steel alloys which retain elastic properties even at high temperature. 2 types of rings- compression and oil rings. Compression ring is upper ring of the piston which provides air tight seal to prevent leakage of the burnt gases into the lower portion. Oil ring is lower ring which provides effective seal to prevent leakage of the oil into the engine cylinder.

**Connecting rod:** It converts reciprocating motion of the piston into circular motion of the crank shaft, in the working stroke. The smaller end of the connecting rod is connected with the piston by gudgeon pin and bigger end of the connecting rod is connected with the crank with crank pin. The special steel alloys or aluminium alloys are used for the manufacture of connecting rod.
Figure 1 shows the different components of IC engine.

![Fig. 1. Different parts of IC engine](image)

**Crankshaft:** It converts the reciprocating motion of the piston into the rotary motion with the help of connecting rod. The special steel alloys are used for the manufacturing of the crankshaft. It consists of eccentric portion called crank.

**Crank case:** It houses cylinder and crankshaft of the IC engine and also serves as sump for the lubricating oil.

**Flywheel:** It is big wheel mounted on the crankshaft, whose function is to maintain its speed constant. It is done by storing excess energy during the power stroke, which is returned during other stroke.

**Terminology used in IC engine:**

1. Cylinder bore (D): The nominal inner diameter of the working cylinder.

2. Stroke (L): The nominal distance through which a working piston moves between two successive reversals of its direction of motion.

3. 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 point of the stroke).

   (a) Bottom dead centre (BDC): Dead centre when the piston is nearest to the crankshaft.

   (b) Top dead centre (TDC): Dead centre when the position is farthest from the crankshaft.

4. Displacement volume or swept volume ($V_s$): The nominal volume generated by the working piston when travelling from the one dead centre to next one and given as,
\[ V_s = A \times L \]

5. Clearance volume \((V_c)\): the nominal volume of the space on the combustion side of the piston at the top dead centre.


\[ V = V_s + V_c \]

**Four stroke engine:**

- Cycle of operation completed in four strokes of the piston or two revolution of the piston.
  (i) Suction stroke (suction valve open, exhaust valve closed)-charge consisting of fresh air mixed with the fuel is drawn into the cylinder due to the vacuum pressure created by the movement of the piston from TDC to BDC.
  (ii) Compression stroke (both valves closed)-fresh charge is compressed into clearance volume by the return stroke of the piston and ignited by the spark for combustion. Hence pressure and temperature is increased due to the combustion of fuel
  (iii) Expansion stroke (both valves closed)-high pressure of the burnt gases force the piston towards BDC and hence power is obtained at the crankshaft.
  (iv) Exhaust stroke (exhaust valve open, suction valve closed)- burned gases expel out due to the movement of piston from BDC to TDC.

Figure 2 show the cycle of operation of four stroke engine.

**Two stroke engine:**

-No piston stroke for suction and exhaust operations

-Suction is accomplished by air compressed in crankcase or by a blower

-Induction of compressed air removes the products of combustion through exhaust ports
Transfer port is there to supply the fresh charge into combustion chamber.

Figure 3 represents operation of two stroke engine.

![Fig. 3. Cycle of operation in two stroke engine](image)

**Comparison of Four-stroke and two-stroke engine:**

<table>
<thead>
<tr>
<th>Four-stroke engine</th>
<th>Two-stroke engine</th>
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<tbody>
<tr>
<td>1. Four stroke of the piston and two revolution of crankshaft</td>
<td>Two stroke of the piston and one revolution of crankshaft</td>
</tr>
<tr>
<td>2. One power stroke in every two revolution of crankshaft</td>
<td>One power stroke in each revolution of crankshaft</td>
</tr>
<tr>
<td>3. Heavier flywheel due to non-uniform turning movement</td>
<td>Lighter flywheel due to more uniform turning movement</td>
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<tr>
<td>4. Power produce is less</td>
<td>Theoretically power produce is twice than the four stroke engine for same size</td>
</tr>
<tr>
<td>5. Heavy and bulky</td>
<td>Light and compact</td>
</tr>
<tr>
<td>6. Lesser cooling and lubrication requirements</td>
<td>Greater cooling and lubrication requirements</td>
</tr>
<tr>
<td>7. Lesser rate of wear and tear</td>
<td>Higher rate of wear and tear</td>
</tr>
<tr>
<td>8. Contains valve and valve mechanism</td>
<td>Contains ports arrangement</td>
</tr>
<tr>
<td>9. Higher initial cost</td>
<td>Cheaper initial cost</td>
</tr>
<tr>
<td>10. Volumetric efficiency is more due to greater time of induction</td>
<td>Volumetric efficiency less due to lesser time of induction</td>
</tr>
<tr>
<td>11. Thermal efficiency is high and also part load efficiency better</td>
<td>Thermal efficiency is low, part load efficiency lesser</td>
</tr>
<tr>
<td>12. It is used where efficiency is important.</td>
<td>It is used where low cost, compactness and light weight are important.</td>
</tr>
</tbody>
</table>

- Ex-cars, buses, trucks, tractors, industrial engines, aero planes, power generation etc.
- Ex-lawn mowers, scooters, motor cycles, mopeds, propulsion ship etc.
Comparison of SI and CI engine:

<table>
<thead>
<tr>
<th></th>
<th>SI engine</th>
<th>CI engine</th>
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<tbody>
<tr>
<td>Working cycle</td>
<td>Working cycle is Otto cycle.</td>
<td>Working cycle is diesel cycle.</td>
</tr>
<tr>
<td>Used fuel</td>
<td>Petrol or gasoline or high octane fuel is used.</td>
<td>Diesel or high cetane fuel is used.</td>
</tr>
<tr>
<td>Ignition temperature</td>
<td>High self-ignition temperature.</td>
<td>Low self-ignition temperature.</td>
</tr>
<tr>
<td>Introduce mixture</td>
<td>Fuel and air introduced as a gaseous mixture in the suction stroke.</td>
<td>Fuel is injected directly into the combustion chamber at high pressure at the end of compression stroke.</td>
</tr>
<tr>
<td>Ignition system</td>
<td>Carburettor used to provide the mixture.</td>
<td>Injector and high pressure pump used to supply of fuel. Quantity of fuel regulated in pump.</td>
</tr>
<tr>
<td>Maximum RPM</td>
<td>Compression ratio is 6 to 10.5</td>
<td>Compression ratio is 14 to 22</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Higher maximum RPM due to lower weight</td>
<td>Lower maximum RPM</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>Maximum efficiency lower due to lower compression ratio</td>
<td>Higher maximum efficiency due to higher compression ratio</td>
</tr>
<tr>
<td>Weight</td>
<td>Lighter</td>
<td>Heavier due to higher pressures</td>
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</tbody>
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