Basics of the gasoline (SI) engine

The gasoline or spark-ignition (SI) internal-combustion engine uses the Otto cycle\(^1\) and externally supplied ignition. It burns an air/fuel mixture and in the process converts the chemical energy in the fuel into kinetic energy.

For many years, the carburetor was responsible for providing an air/fuel mixture in the intake manifold which was then drawn into the cylinder by the downgoing piston.

The breakthrough of gasoline fuel injection, which permits extremely precise metering of the fuel, was the result of the legislation governing exhaust-gas emission limits. Similar to the carburetor process, with manifold fuel injection the air/fuel mixture is formed in the intake manifold.

Even more advantages resulted from the development of gasoline direct injection, in particular with regard to fuel economy and increases in power output. Direct injection injects the fuel directly into the engine cylinder at exactly the right instant in time.

\(\text{Method of operation}\)

The combustion of the air/fuel mixture causes the piston (Fig. 1, Pos. 8) to perform a reciprocating movement in the cylinder (9). The name reciprocating-piston engine, or better still reciprocating engine, stems from this principle of functioning.

The conrod (10) converts the piston’s reciprocating movement into a crankshaft (11) rotational movement which is maintained by a flywheel at the end of the crankshaft. Crankshaft speed is also referred to as engine speed or engine rpm.

\(\text{Four-stroke principle}\)

Today, the majority of the internal-combustion engines used as vehicle power plants are of the four-stroke type. The four-stroke principle employs gas-exchange valves (5 and 6) to control the exhaust-and-refill cycle. These valves open and close the cylinder’s intake and exhaust passages, and in the process control the supply of fresh air/fuel mixture and the forcing out of the burnt exhaust gases.
1st stroke: Induction
Referred to Top Dead Center (TDC), the piston is moving downwards and increases the volume of the combustion chamber (7) so that fresh air (gasoline direct injection) or fresh air/fuel mixture (manifold injection) is drawn into the combustion chamber past the opened intake valve (5).

The combustion chamber reaches maximum volume \(V_h + V_c\) at Bottom Dead Center (BDC).

2nd stroke: Compression
The gas-exchange valves are closed, and the piston is moving upwards in the cylinder. In doing so it reduces the combustion-chamber volume and compresses the air/fuel mixture. On manifold-injection engines the air/fuel mixture has already entered the combustion chamber at the end of the induction stroke. With a direct-injection engine on the other hand, depending upon the operating mode, the fuel is first injected towards the end of the compression stroke.

At Top Dead Center (TDC) the combustion-chamber volume is at minimum (compression volume \(V_c\)).

3rd stroke: Power (or combustion)
Before the piston reaches Top Dead Center (TDC), the spark plug (2) initiates the combustion of the air/fuel mixture at a given ignition point (ignition angle). This form of ignition is known as externally supplied ignition. The piston has already passed its TDC point before the mixture has combusted completely.

The gas-exchange valves remain closed and the combustion heat increases the pressure in the cylinder to such an extent that the piston is forced downward.

4th stroke: Exhaust
The exhaust valve (6) opens shortly before Bottom Dead Center (BDC). The hot (exhaust) gases are under high pressure and leave the cylinder through the exhaust valve. The remaining exhaust gas is forced out by the upwards-moving piston.

A new operating cycle starts again with the induction stroke after every two revolutions of the crankshaft.

Valve timing
The gas-exchange valves are opened and closed by the cams on the intake and exhaust camshafts (3 and 1 respectively). On engines with only 1 camshaft, a lever mechanism transfers the cam lift to the gas-exchange valves.

The valve timing defines the opening and closing times of the gas-exchange valves. Since it is referred to the crankshaft position, timing is given in “degrees crankshaft”. Gas flow and gas-column vibration effects are applied to improve the filling of the combustion chamber with air/fuel mixture and to remove the exhaust gases. This is the reason for the valve opening and closing times overlapping in a given crankshaft angular-position range.

The camshaft is driven from the crankshaft through a toothed belt (or a chain or gear pair). On 4-stroke engines, a complete working cycle takes two rotations of the crankshaft. In other words, the camshaft only turns at half crankshaft speed, so that the step-down ratio between crankshaft and camshaft is 2:1.