3 RECIPROCATING INTERNAL COMBUSTION ENGINES

Piston machines occupy a prominent place among internal combustion engines. This situation stems from two causes:

1) By their periodical operation, these machines are particularly suitable for processes where the temperature reaches high values. Being in contact with the fluid at various stages of process, the walls of the machine are subject to an average temperature well below the maximum temperature, whereas in a continuous flow machine such as gas turbine, some parts are constantly subjected to this temperature. In addition, the velocities being much lower in piston machines, the fluid/wall exchange coefficients are smaller. Finally, the average heat flux received by the walls is low enough that, with adequate cooling, we can keep them in good working condition while producing inside the cylinder combustion at more than 2500 K, which as we have seen in section 2.1.3, would be quite impossible in a continuous flow machine.

2) Internal combustion engines are widely used for propulsion of vehicles of small and medium capacity. Indeed the piston engine adapts much better to this use than the turbine engine, which is feasible only with very high characteristic speed, and therefore must rotate at considerable speed when power is moderate, with interposition of fragile and expensive reducing gear.

It is customary to distinguish the modes of operation of spark ignition and diesel engines by characterizing each by a different cycle, the Beau de Rochas cycle (or Otto depending on the authors) is characterized by a constant volume combustion and the diesel cycle by combustion at constant pressure. In fact, especially in fast engines, we will see later that the combustion delays are such that more complex cycles must be considered if one wishes to be precise. In these circumstances, what distinguishes the two types of engines is not so much the theoretical cycle than combustion characteristics, including kinetics, studied in section 4.6.1 of Part 2, which follow very different laws depending on whether the fuel is volatile or not. So we understand that the complexity of the physicochemical phenomena taking place during combustion in an engine piston is such that the basic ideal cycles just allow approaching reality in a relatively simplified way.

3.1 GENERAL OPERATION MODE

Animations illustrating the operation of these engines were made by the French Navy and soundtracks added in Diapason sessions S35_PBV and S35_4t2t to which we recommend you refer[1] to supplement the explanations in this section.

All reciprocating internal combustion engines operate on the same general process described schematically Figure 3.1.1. A variable volume is defined by a cylinder, one of the bases of which is fixed, called head, and the other is a movable piston in the cylinder bore, driven by a connecting rod system. In a four-stroke engine, the organs that control the inlet or exhaust valves are actuated by push buttons coupled to the drive shaft by a camshaft.

---

[1] http://www.thermoptim.org/sections/technologies/systemes/maci

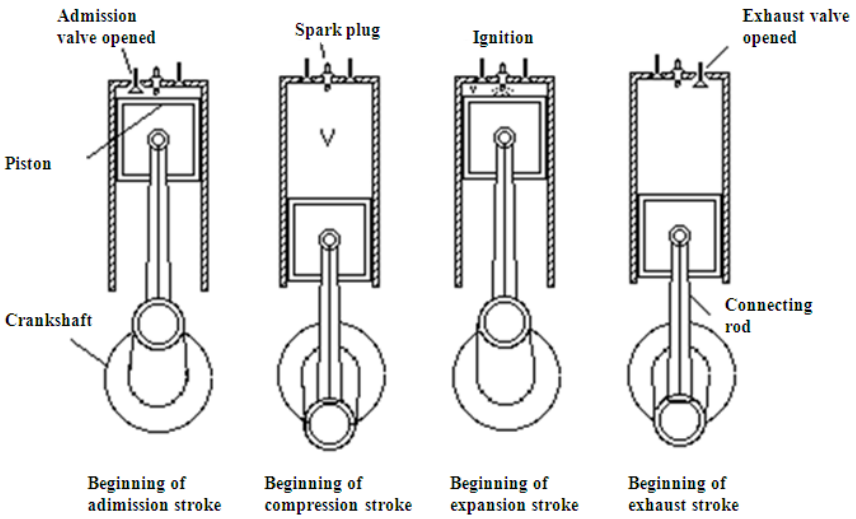

Figure 3.1.1: Four-stroke operation mode

In various ways, depending on whether the engine is two or four stroke (see section 3.1.1), fresh gas is introduced into the cylinder at atmospheric pressure during the intake phase (fuel mixture formed in advance in conventional gasoline engines, clean air in diesel engines).

The piston being at a distance from the bottom of the cylinder, the intake port is closed, the volume V between the piston and the bottom being occupied by a certain charge of fresh gas.

Approaching the bottom of the cylinder, the piston compresses the charge in the volume v of the combustion chamber, that is to say the remaining space when the piston reaches the end of his stroke, called top dead center or TDC. This compression is substantially adiabatic and occurs without appreciable internal friction. The key factor is the operating volumetric compression ratio $\rho = V/v$, a geometric characteristic of the cylinder.

The combustion reaction is then triggered, either by local ignition of the mixture in gasoline engines or by injecting fuel into the compressed air in diesel engines. The combustion occurs during a relatively short time, while the piston continues its stroke. In practice, it occurs in a mode intermediate between the constant volume combustion and combustion at constant pressure. The piston continuing to move away from the bottom of the cylinder, the burned gases expand until the end of the stroke (bottom dead center or BDC), then are evacuated and replaced by a new charge of fresh gas.