2.1 Otto Analysis & Optimization

An Otto cycle is an idealized thermodynamic cycle that describes the functioning of a typical spark ignition piston engine. It is the thermodynamic cycle most commonly found in automobile engines.

The Otto cycle is a description of what happens to a mass of gas as it is subjected to changes of pressure, temperature, volume, addition of heat, and removal of heat. The mass of gas that is subjected to those changes is called the system. The system, in this case, is defined to be the fluid (gas) within the cylinder. By describing the changes that take place within the system, it will also describe in inverse, the system's effect on the environment. In the case of the Otto cycle, the effect will be to produce enough net work from the system so as to propel an automobile and its occupants in the environment.

The Otto cycle is constructed from:

Top and bottom of the loop: a pair of quasi-parallel and isentropic processes

(frictionless, adiabatic reversible).

Left and right sides of the loop: a pair of parallel isochoric processes (constant volume).

The isentropic process of compression or expansion implies that there will be no inefficiency (loss of mechanical energy), and there be no transfer of heat into or out of the system during that process. Hence the cylinder, and piston are assumed impermeable to heat during that time. Work is performed on the system during the lower isentropic compression process. Heat flows into the Otto cycle through the left pressurizing process and some of it flows back out through the right depressurizing process. The summation of the work added to the system plus the heat added minus the heat removed yields the net mechanical work generated by the system.

The processes are described by:

Process 0–1 a mass of air is drawn into piston/cylinder arrangement at constant pressure.

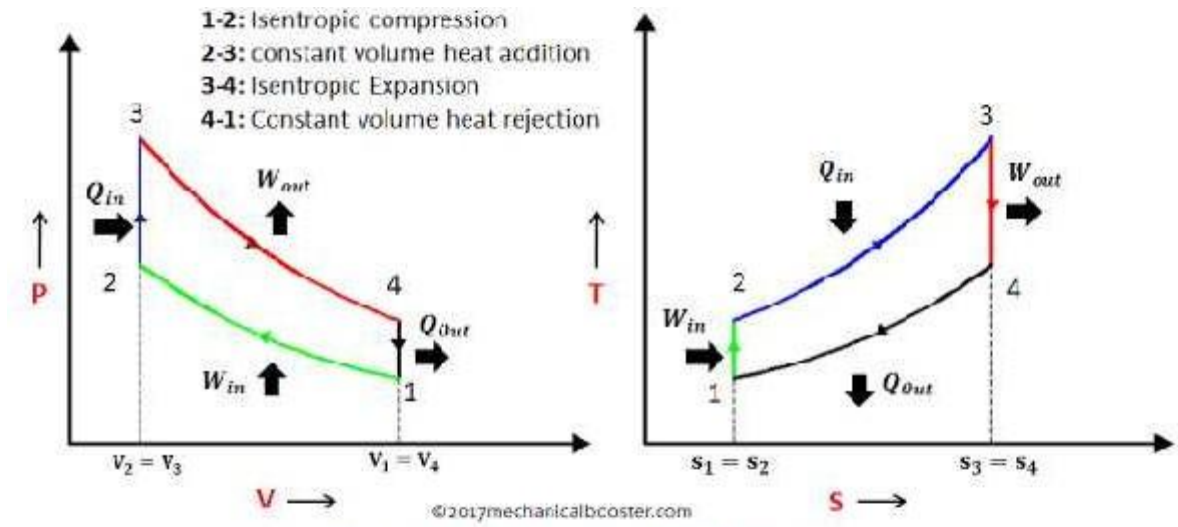
Process 1–2 is an adiabatic (isentropic) compression of the charge as the piston moves from bottom dead centre (*BDC*) to top dead centre (*TDC*).

Process 2–3 is a constant-volume heat transfer to the working gas from an external source while the piston is at top dead centre. This process is intended to represent the ignition of the fuel-air mixture and the subsequent rapid burning.

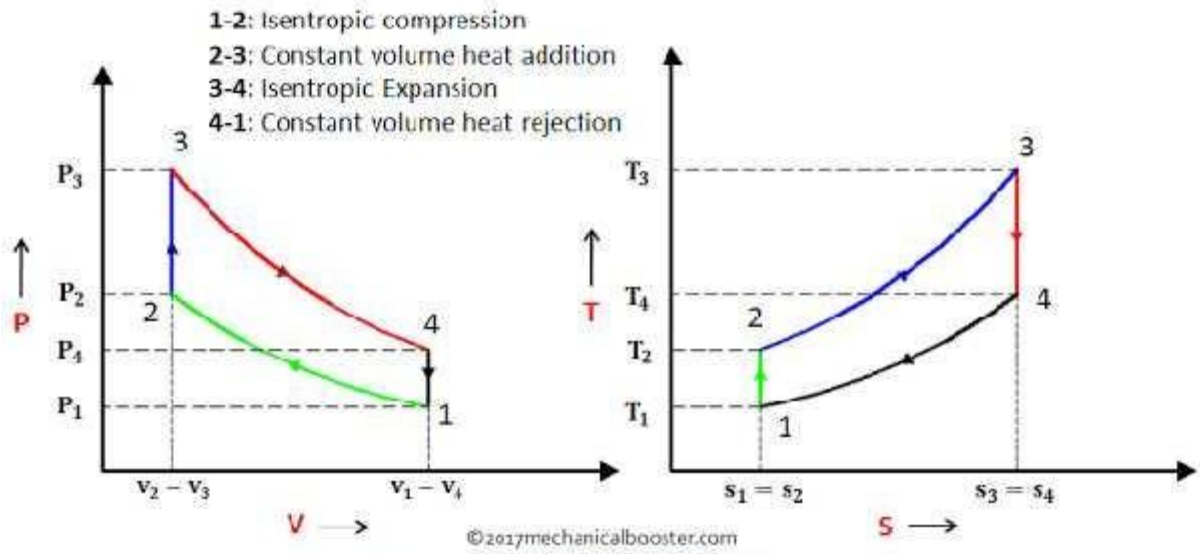
Process 3–4 is an adiabatic (isentropic) expansion (power stroke).

Process 4–1 completes the cycle by a constant-volume process in which heat is rejected from the air while the piston is at bottom dead centre.

Process 1–0 the mass of air is released to the atmosphere in a constant pressure process.



P-V and T-S Diagram of Otto Cycle



P-V and T-S Diagram of Otto Cycle

The efficiency of Otto cycle is given by

$$\eta_{Otto} = \eta_{th} = 1 - \frac{T_4 - T_3}{T_2 - T_1} = 1 - \frac{1}{r^{(\gamma-1)}}$$

$$\eta_{th} = 1 - \frac{T_4 - T_3}{T_2 - T_1} = 1 - \frac{1}{r^{(\gamma-1)}}$$

$$r = \text{Compression ratio} = \frac{V_1}{V_2} = \frac{V_4}{V_3}$$

$$\gamma = adiabatic\ index$$