Diesel Cycle

(four stroke CI-engine, ideal cycle)

The Compress - Ignition (CI) engine was first proposed by Rudolf Diesel in the 1890s. Here how a four stroke diesel engine works will be shortly described:

1. Intake Stroke:
   The inlet valve opens when the piston reaches the TDC and air is allowed to flow into the cylinder through the intake manifold. The piston moves from TDC towards BDC.
2. Compression Stroke:
   The piston moves back up towards TDC and compress the air
3. Expansion Stroke due to combustion:
   As the piston reaches the TDC, fuel is injected directly into the cylinder. Due to the high temperature of compressed air in the cylinder, fuel is ignited, consumed and heat is released. Piston is forced to move towards BDC again.
4. Exhaust Stroke:
   During this stroke the exhaust valve is opened and the piston moves back towards TDC, pushing the exhaust out of the cylinder into exhaust manifold.

The facts that, for example,

- the intake valve opens before TDC and closes after BDC
- the exhaust process begins before DBC and ends after TDC
- and so on

are not taken into consideration. They, however, play significant rolls in internal combustion engines. For more detailed discussion, literatures concerning internal combustion engine are strongly recommended.

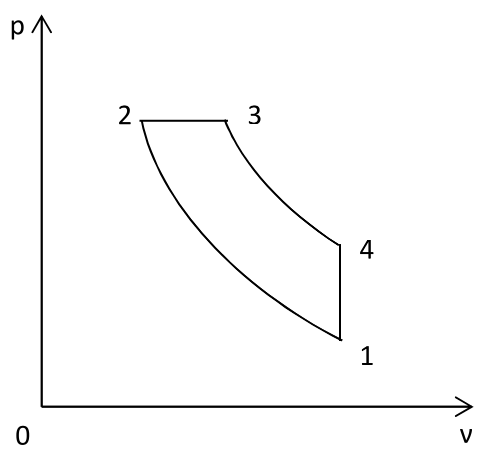
This four stroke diesel engine can be idealized as the following four reversible processes:

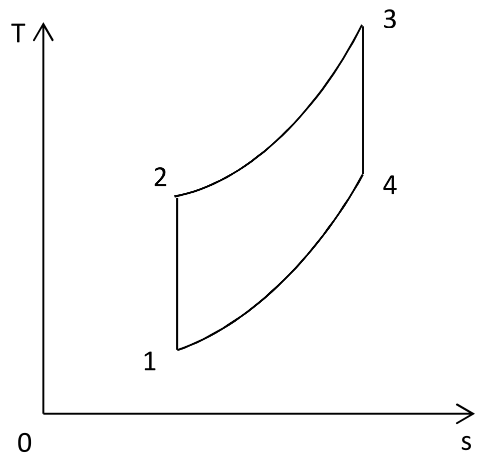
1→2: isentropic compression (compression stroke)

2→3: heat release due to combustion of fuel at constant pressure (expansion stroke)

3→4: isentropic expansion (expansion stroke)

4→1: heat rejection at constant volume (exhaust and intake stroke)





Furthermore, in this idealized process working fluid is considered to be air which behaves as perfect gas. That means, air follows the ideal gas equation.

What's more, the idealized diesel cycle is characterized by a closed system which follows the 1 law of thermodynamics for the closed system.

The assumptions mentioned above allow us to calculate the thermal efficiency of the idealized diesel cycle:

2→3:

$$q_{release} + w_{rev} = u_3 - u_2$$

where: $w_{rev} = -p_2 \cdot (v_3 - v_2)$

$$q_{release} = u_3 - u_2 - w_{rev} = u_3 - u_2 - (-p_2 \cdot (v_3 - v_2))$$

$$= (u_3 + p_2 \cdot v_3) - (u_2 + p_2 \cdot v_2) = h_3 - h_2 = c_p \cdot (T_3 - T_2)$$

4→1:

$$q_{rejection} + w_{rev} = u_1 - u_4$$

where: $w_{rev} = 0$ because of constant volume

$$q_{rejection} = u_1 - u_4 = c_v \cdot (T_1 - T_4)$$

Therefore the thermal efficiency of diesel cycle is:

$$\eta_{th,D} = \frac{q_{release} + q_{reject}}{q_{release}} = \frac{c_p \cdot (T_3 - T_2) + c_v \cdot (T_1 - T_4)}{c_p \cdot (T_3 - T_2)} = 1 - \frac{c_v}{c_p} \cdot \frac{T_4 - T_1}{T_3 - T_2}$$

By using:

- the compression ratio $\varepsilon = v_{max} / v_{min} = v_1 / v_2$
- the cutoff ratio $r_c = v_3 / v_2$
- the specific heat ratio $\kappa = c_p / c_v$

the thermal efficiency can be now expressed as:

$$\eta_{th,D} = 1 - \frac{1}{\varepsilon^{\kappa-1}} \cdot \left[\frac{r_c^{\kappa} - 1}{\kappa \cdot (r_c - 1)}\right]$$