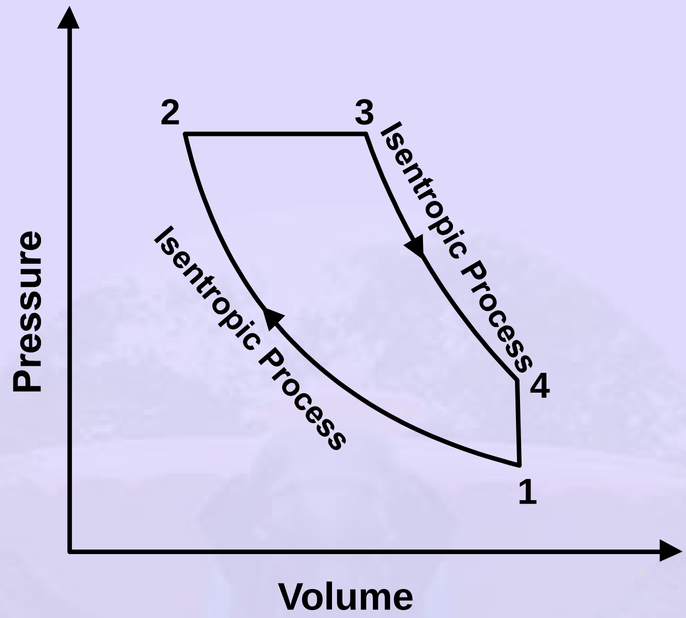
4.5 Air Standard Diesel Cycle:

Air standard diesel cycle is a idealized cycle for diesel engines. It is as shown on P-v and T-s diagrams. The processes in the cycle are as follows:



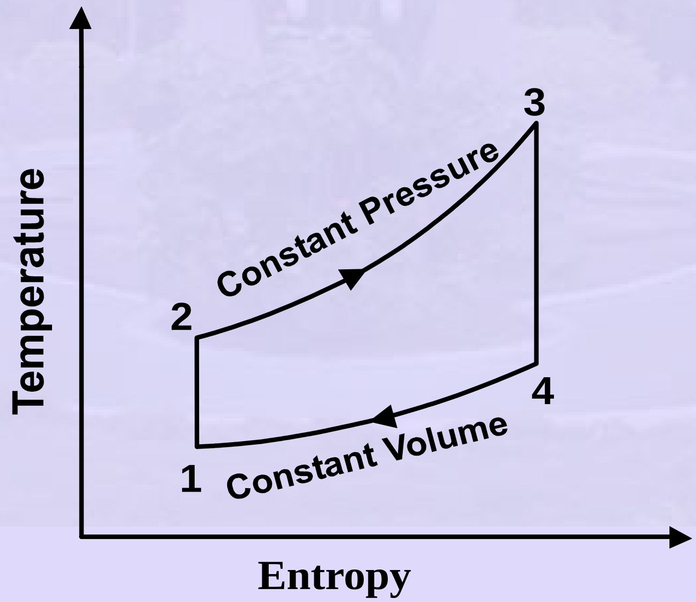


Fig.4.5. Air standard diesel cycle on p-v and T-s diagrams.

Process 1-2: Reversible adiabatic Compression.

Process 2-3: Constant pressure heat addition.

Process 3-5: Reversible adiabatic Compression.

Process 4-1: Constant volume heat rejection.

Consider 'm' kg of working fluid. Since the compression and expansion processes are reversible adiabatic processes, we can write,

$$\text{Heat supplied} = m\,C_p\left(T_3 - T_2\right) = \left(h_3 - h_2\right)$$

$$\text{Heat rejected} = m\,C_v\left(T_4 - T_1\right) = \left(u_4 - u_1\right)$$

$$\text{Workdone} = m\,C_p\left(T_3 - T_2\right) - m\,C_v\left(T_4 - T_1\right)$$

Now, we can write, thermal efficiency as,

$$\eta_{th} = \frac{m\,C_p\left(T_3 - T_2\right) - m\,C_v\left(T_4 - T_1\right)}{m\,C_p\left(T_3 - T_2\right)}$$

$$= 1 - \frac{1}{\gamma}\left(\frac{T_4 - T_1}{T_3 - T_2}\right)$$

$$T_2 = T_1\,r^{\gamma-1} \; ; \quad r = \frac{v_1}{v_2} = \frac{v_4}{v_2}$$

$$\frac{T_3}{T_2} = \frac{v_3}{v_2} = r_c = \text{cutoff ratio}$$

$$T_3 = r_c\,T_2 = r_c\,T_1\,r^{\gamma-1}$$

$$T_4 = T_3\left(\frac{v_3}{v_4}\right)^{\gamma-1} = T_3\left(\frac{v_4}{v_3}\right)^{\gamma-1}$$

$$= T_3\left(\frac{v_4}{v_2}.\frac{v_2}{v_3}\right)^{1-\gamma} = T_3\left(\frac{r}{r_c}\right)^{1-\gamma}$$

$$= r_c\ T_1\ r^{\gamma-1}\left(\frac{r}{r_c}\right)^{1-\gamma} \quad ; \quad T_4 = r_c^{\gamma}\ T_1$$

Hence,
$$\eta_{th} = 1 - \frac{1}{\gamma}\left\{\frac{r_c^{\gamma}\ T_1 - T_1}{r_c\ r^{\gamma-1}\ T_1 - r^{\gamma-1}\ T_1}\right\}$$

$$= 1 - r^{1-\gamma}\left\{\frac{r_c^{\gamma} - 1}{\gamma\left(r_c - 1\right)}\right\}$$

From the above equation, it is observed that, the thermal efficiency of the diesel engine can be increased by increasing the compression ratio, r, by decreasing the cut-off ratio, α_2, or by using a gas with large value of γ. Since the quantity $(r^{\gamma}-1)/\gamma(r_p-1)$ in above equation is always greater than unity, the efficiency of a Diesel cycle is always lower than that of an Otto cycle having the same compression ratio. However, practical Diesel engines uses higher compression ratios compared to petrol engines.

Mean effective Pressure:

$$mep = \frac{\text{Net workdone}}{\text{Displacement volume}}$$

$$= \frac{m\ C_p\left(T_3 - T_2\right) - m\ C_v\left(T_4 - T_1\right)}{v_1 - v_2}$$

$$v_1 - v_2 = v_1\left(1 - \frac{v_2}{v_1}\right) = v_1\left(1 - \frac{1}{r}\right)$$

$$= m\ R\ T_1\left(\frac{r - 1}{r}\right)$$

$$= \frac{m\ C_v\left(\gamma - 1\right)\ T_1}{P_1}\left(\frac{r - 1}{r}\right)$$

$$mep = \frac{m\,C_p\left(T_3 - T_2\right) - m\,C_v\left(T_4 - T_1\right)}{m\,C_v T_1\left(\frac{\gamma - 1}{P_1}\right)\left(\frac{r - 1}{r}\right)}$$

$$= \left(\frac{P_1\,r}{r - 1}\right)\left(\frac{1}{\gamma - 1}\right)\left\{\gamma\left(\frac{T_3 - T_2}{T_1}\right) - \left(\frac{T_4 - T_1}{T_1}\right)\right\}$$

$$= P_1\,r\left\{\frac{\gamma\,r^{\gamma-1}\left(r_c - 1\right) - \left(r_c^{\gamma} - 1\right)}{\left(r - 1\right)\left(\gamma - 1\right)}\right\}$$

Difference between Actual Diesel and the Otto Engines:

Otto Engine	Diesel Engine
1. Homogenous mixture of fuel and air formed in the carburetor is supplied to engine cylinder.	1. No carburetor is used. Air alone is supplied to the engine cylinder. Fuel is injected directly into the engine cylinder at the end of compression stroke by means of a fuel injector. Fuel-air mixture is heterogeneous.
2. Ignition is initiated by means of an electric spark plug.	2. No spark plug is used. Compression ratio is high and the high temperature of air ignites fuel.
3. Power output is controlled by varying the mass of fuel-air mixture by means of a throttle valve in the carburetor.	3. No throttle value is used. Power output is controlled only by means of the mass of fuel injected by the fuel injector.