5-The Diesel (or Constant Pressure) Cycle:

Air standard diesel cycle is an idealized cycle for diesel engines. It is as shown on P-v and T-s diagrams. This thermodynamics cycle is called constant pressure cycle because heat is supplied to the air at constant pressure. The processes in the cycle are as follows:

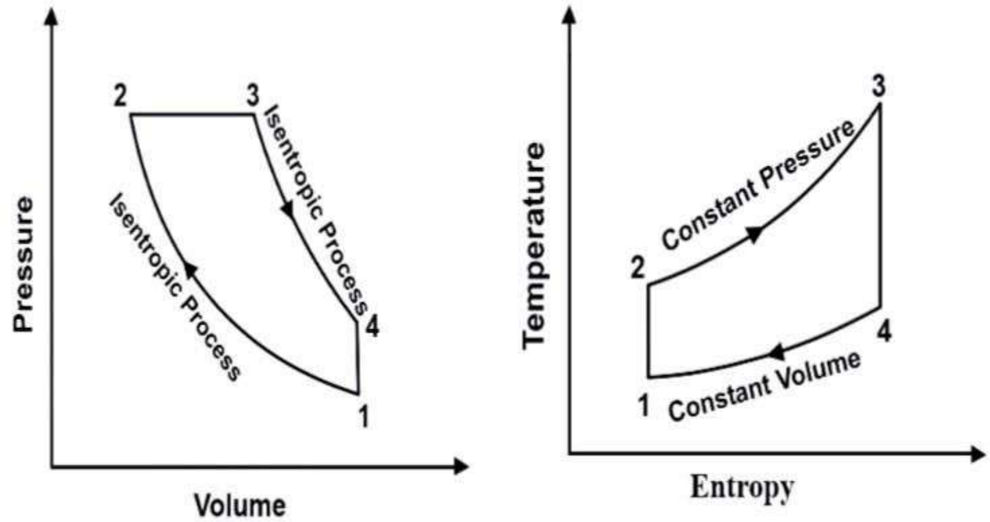

Figure 3: Air standard diesel cycle on p-v and T-s diagrams of a cycle with constant pressure heat addition

Process 1-2: Isentropic (Reversible adiabatic) compression of the gas from the initial volume, V_1, to the minimum volume (clearance volume), V_2, according to $PV^{\gamma}=C$ (Negative Work done ,W.D., on the gas) i.e

$PV^{\gamma}=C$; $TV^{\gamma-1}=C$; $\frac{T}{P^{\frac{\gamma-1}{\gamma}}}=C$; $Q_{12}=0$; $r_c= V_1/V_2$; $W_{12}=\frac{P_1V_1-P_2V_2}{\gamma-1}=\frac{mR(T_1-T_2)}{\gamma-1}$

Process 2-3: Constant pressure heat addition; The heat added at constant pressure while the piston is moving. i.e. the volume is increasing from V_2 to V_3. The volume V_3 is called the (cut – off volume) and the point 3 is called (cut – off point), therefore, cut off volume is defined as the volume at which the heat addition is stopped. The ($r_{off}= V_3/V_2$) is called cut off ratio or Isobaric expansion ratio is the ratio between cut – off volume to the minimum volume in the cycle; i.e. ; $P_2=P_3$; $\frac{V}{T}=C$; Work done (W.D.) $W_{23}=\int_{V_2}^{V_3} P\,dv = P(V_3-V_2)$

Heat supplied = Q_{23} = $m\,C_p\,(T_3 - T_2)$ &

Now, Cut off raio (r_{off})is the ratio between cut off Volume to the minimum Volume in the cycle ($r_{off}= V_3/V_2$) .

3. **Process 3-4**: isentropic expansion according to $PV^{\gamma}=C$ until the initial Volume is reached (+ve W.D). The ratio of the maximum volume to the cut off Volume is called expansion ratio and equal: ($r_e= V_4/V_3$) , and in this process

$$Q_{34}=0\ ,\ W_{34}=\frac{P_3V_3-P_4V_4}{\gamma-1}=\frac{mR(T_3-T_4)}{\gamma-1}\ \text{and}\ PV^{\gamma}=c,\ TV^{\gamma-1}=c,\ \frac{T}{P^{\frac{\gamma-1}{\gamma}}}=c$$

Process 4-1: Heat rejected at constant volume which brings the gas back to the original condition (state 1).

Dividing Compression ratio to cut off ratio

$$\frac{r_c}{r_{off}}=\frac{V_1}{V_2}*\frac{V_2}{V_3}=\frac{V_1}{V_3}\ ,\ \because V_1=V_4\ \therefore \frac{r_c}{r_{off}}=\frac{V_1}{V_3}=\frac{V_4}{V_3}=r_e\ ,\ \therefore r_e=\frac{r_c}{r_{off}}$$

This cycle is the theoretical cycle for compression-ignition or diesel engine. For this cycle: Consider 'm' kg of working fluid. Since the compression and expansion processes are reversible adiabatic processes, we can write,

Heat supplied = Q_1 = $m\,C_p\,(T_3 - T_2) = (h_3 - h_2)$

Heat rejected = Q2 = $m\,C_v\,(T_4 - T_1) = (u_4 - u_1)$

Work done = $m\,C_p\,(T_3 - T_2) - m\,C_v\,(T_4 - T_1)$

Now, we can write, thermal efficiency as,

$\eta = (m\,C_p(T3 - T2) - m\,C_v\,(T4 - T1))/(m\,C_p(T3 - T2))$

$$\eta=1-\frac{Q_2}{Q_1}=1-\frac{1}{\gamma}\left(\frac{T_4-T_1}{T_3-T_2}\right)$$

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

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

$$\eta = 1 - \frac{1}{\gamma\left(\frac{V_1}{V_2}\right)^{\gamma-1}}\left(\frac{\left(\frac{V_3}{V_2}\right)^{\gamma} - 1}{\left(\frac{V_3}{V_2}\right) - 1}\right)$$

$\frac{V_1}{V_2} = r$ and $\frac{V_3}{V_2} = \beta$, then:

$$\eta = 1 - \frac{\beta^{\gamma} - 1}{(\beta - 1)\gamma r^{\gamma-1}}$$

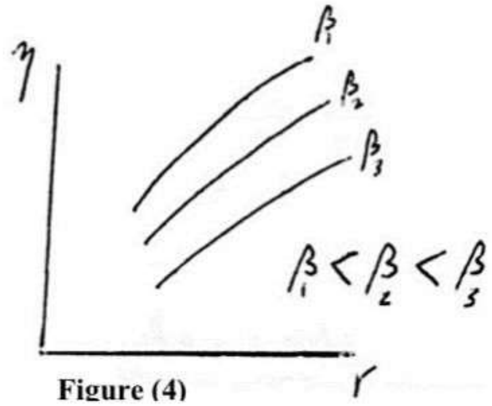

Figure (4)

This equation shows that thermal efficiency depends not only on the compression ratio ($r=V_1/V_2$) **or (r_c)** but also on the cut-off ratio (**r**$_{off}$) $\beta = V_3/V_2$ and the working medium properties γ. As the cut-off ratio increase the work done per cycle increase **but η decreases**. When the compression ratio (r) increases more than 22, the increase in **η** is small, on the other hand, maximum pressure increases much and mass of the engine increases.
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, or by using a gas with large value of γ. Since 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.

Apparently, the efficiency of diesel cycle depends upon the compression ratio (r) and cutoff ratio (β) and hence upon the quantity of heat supplied. Figure 4; shows the air standard efficiency of diesel cycle for various cut off ratio.