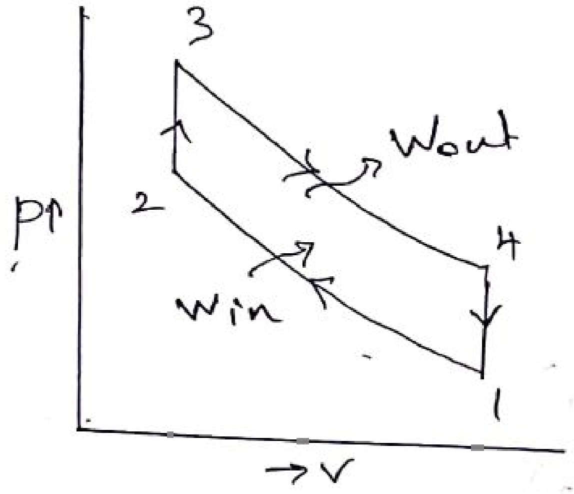
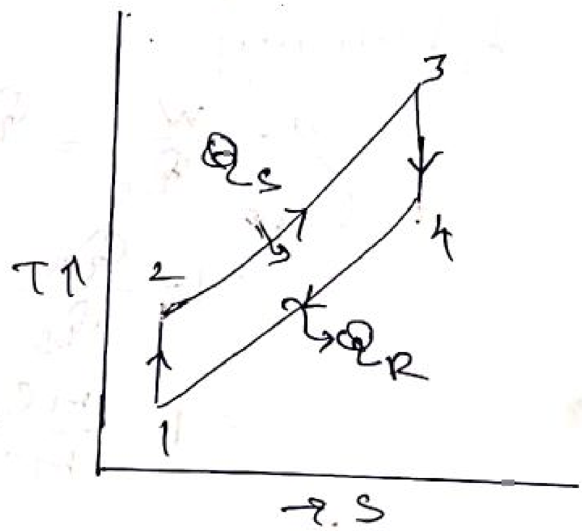
DEPT: MECH YEAR: II
Sub: Thermal Engg-I

Otto cycle: UNIT-I

* Two Iso-choric process
* Two Isentropic process
* Application: petrol Engine.





Process ① - ②

* Isentropic Compression
* $pv^{\gamma} = c$ * $r_c = \frac{V_1}{V_2} = r$
* p↑, v↓, T↑, s = c

Process ② - ③

* Iso-choric Heating process [v = c]
* p↑, v = c, T↑, s↑
* $Q_s = m\,C_v(T_3 - T_2)$

Process ③ - ④

* Isentropic Expansion
* p↓, v↑, T↓, s = c
* $pv^{\gamma} = c$
* $r_e = r = \frac{V_4}{V_3} = \frac{V_1}{V_2}$

Process (4) – (1)

* Iso-choric Heat Rejection

* $P\downarrow, V = C, T\downarrow, S\downarrow$

* $Q_R = m C_v (T_4 - T_1)$

Efficiency

$$\eta = \frac{W}{Q_s} = \frac{Q_s - Q_R}{Q_s}$$

$$= 1 - \frac{Q_R}{Q_s}$$

$$= 1 - \frac{m C_v (T_4 - T_1)}{m C_v (T_3 - T_2)}$$

$$\boxed{\eta_{otto} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}} \quad \text{———— I}$$

From p-v & T-s Diagram

* $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \quad \frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

* $\frac{T_2}{T_1} = \frac{T_3}{T_4} \Rightarrow \frac{T_4}{T_1} = \frac{T_3}{T_2}$

* $\frac{T_4}{T_1} - 1 = \frac{T_3}{T_2} - 1$

* $\frac{T_4 - T_1}{T_1} = \frac{T_3 - T_2}{T_2}$

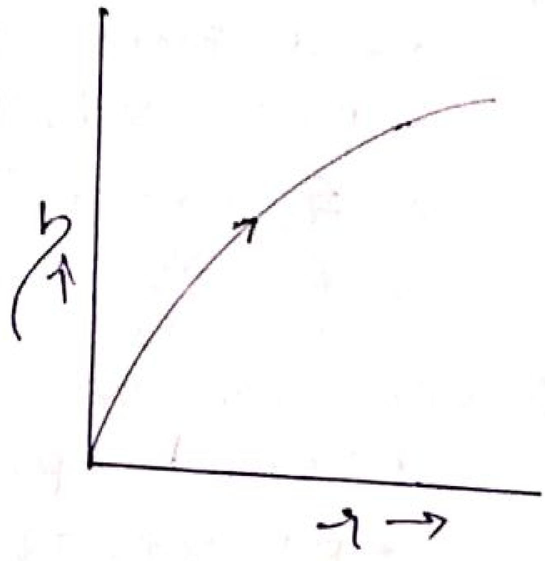
* $\frac{T_4 - T_1}{T_3 - T_2} = \frac{T_1}{T_2}$ ———— 2

(2) in (1)

$$\eta = 1 - \frac{T_1}{T_2}$$

$$= 1 - \frac{1}{\frac{T_2}{T_1}}$$

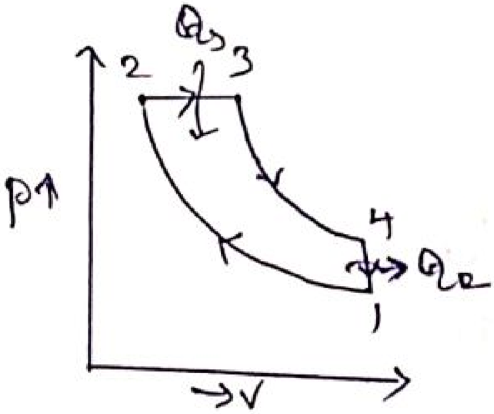
$$\boxed{\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}}$$

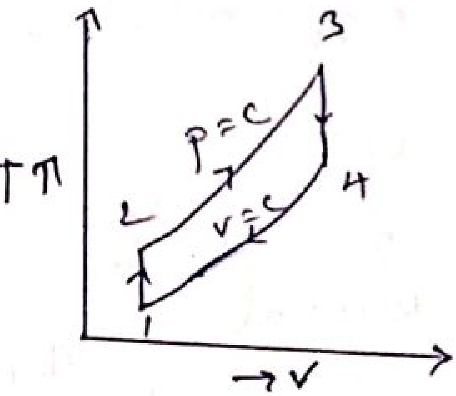


Diesel cycle:

* Two Isentropic process
* one Iso-baric process
* one Iso-choric process

→ Application: Diesel engine.





Process (1) - (2)

* Isentropic Compression - $pv^{\gamma} = c$
* $P\uparrow, V\downarrow, T\uparrow, S = C$
* $r_c = \frac{V_1}{V_2} = r$

Process (2) - (3)

* Iso-Baric process - Heating

* $p = c$, $V\uparrow$, $T\uparrow$, $S\uparrow$

* $Q_s = mC_p(T_3 - T_2)$

* $\rho = \frac{V_3}{V_2}$ - cutt off ratio

Process (3) - (4)

* Isentropic Expansion - $pv^\gamma = c$

* $P\downarrow$, $V\uparrow$, $T\downarrow$, $S = c$

* $r_e = \frac{V_4}{V_3} \Rightarrow r_e = \frac{V_1}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3}$

$r_e = r/\rho$

Process (4) - (1)

* Iso-choric Heat Rejection

* $P\downarrow$, $V = c$, $T\downarrow$, $S\downarrow$

* $Q_R = mC_v(T_4 - T_1)$.

Efficiency:

$$\eta_{Diesel} = \frac{W}{Q_s} = \frac{Q_s - Q_R}{Q_s}$$

$$= 1 - Q_R/Q_s$$

$$= 1 - \frac{mC_v(T_4 - T_1)}{mC_p(T_3 - T_2)}$$

$$\boxed{\eta_{Diesel} = 1 - \frac{(T_4 - T_1)}{\gamma(T_3 - T_2)}} \longrightarrow \text{I}$$

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Process ① – ② $pv^{\gamma} = c$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\boxed{T_2 = T_1\, r^{\gamma-1}} \quad \text{——— (2)}$$

Process ② – ③ $p = c$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2}$$

$$T_3 = T_2 \cdot \rho$$

$$\boxed{T_3 = T_1 \cdot \rho \cdot r^{\gamma-1}} \quad \text{——— (3)}$$

Process ③ – ④

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$T_4 = T_3 \cdot \frac{1}{r_e^{\gamma-1}}$$

$$= T_3 \cdot \frac{\rho^{\gamma-1}}{r^{\gamma-1}}$$

$$= T_1 \times \rho \times r^{\gamma-1} \times \frac{\rho^{\gamma-1}}{r^{\gamma-1}}$$

$$\boxed{T_4 = T_1 \times \rho^{\gamma}} \quad \text{——— (4)}$$

②, ③, ④ at (I)

$$\eta_{Diesel} = 1 - \frac{1}{\gamma}\left[\frac{T_1 \rho^\gamma - T_1}{T_1 r^{\gamma-1}\rho - T_1 r^{\gamma-1}}\right]$$

$$= 1 - \frac{1}{\gamma} \frac{T_1 (\rho^\gamma - 1)}{T_1 r^{\gamma-1}(\rho - 1)}$$

$$\boxed{\eta_{Diesel} = 1 - \frac{1}{\gamma r^{\gamma-1}} \frac{(\rho^\gamma - 1)}{(\rho - 1)}}$$

An engine with 200 mm cylinder diameter and 300 mm stroke works on theoretical Diesel cycle. The initial pressure and temperature of air used are 1 bar and 27°C. The cut off is 8% of the stroke. Determine.

(i) pressure and temperature at all point

(ii) Theoretical air standard efficiency

(iii) Mean effective pressure

(iv) power of the engine if the working cycles per minutes are 380

Assume that the compression ratio is 15 and working fluid is air.

Given data:

$d = 200mm = 0.2m$

$l = 300mm = 0.3m$

$P_1 = 1 \text{ bar} = 100 kpa$

$T_1 = 27°c = 300k$

Cut-off = 8 % of V_s

$r = 15$

N = 380 cycles/min

To find

* $P_2, P_3, P_4, T_2, T_3, T_4$
* η_{Diesel}
* P_m
* power output

solution:

(i) pressure & Temperature at all point

$$V_s = \frac{\pi}{4} d^2 l$$

$$= \frac{3.14}{4} \times 0.2^2 \times 0.3$$

$$V_s = 9.43 \times 10^{-3} m^3$$

$$r = \frac{V_1}{V_2} = \frac{V_c + V_s}{V_c}$$

$$r = 1 + \frac{V_s}{V_c}$$

$$V_c = \frac{V_s}{r-1}$$

$$V_1 = V_s + V_c$$

$$= V_s + \frac{V_s}{r-1}$$

$$= 9.43\times10^{-3} + \frac{9.43\times10^{-3}}{15-1}$$

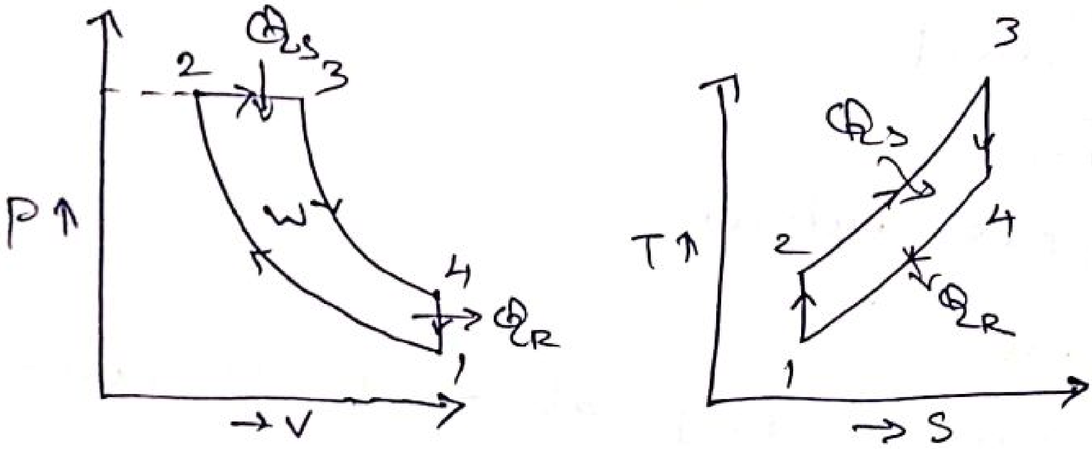
$$V_1 = 0.01\ m^3$$

$$P_1V_1 = mRT_1$$

$$m = \frac{P_1V_1}{RT_1}$$

$$= \frac{100\times0.01}{0.287\times300}$$

$$m = 0.012\ kg$$



① – ② → $PV^\gamma = C$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma$$

$$P_2 = P_1 \times r^\gamma$$

$$= 100\times15^{1.4}$$

$$\boxed{P_2 = 44.31\ bar}$$

· Process ② - ③

$P_2 = P_3 = 44.31$ bar

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$$

$$T_2 = T_1 \times r^{\gamma - 1}$$

$$= 300 \times 15^{1.4 - 1}$$

$$\boxed{T_2 = 886.25\,K = 613.25^\circ C}$$

Compression ratio

$$r = \frac{V_1}{V_2}$$

$$15 = \frac{0.01}{V_2}$$

$$V_2 = 6.67 \times 10^{-4}\ m^3$$

Cut-off = 8% of V_s

$$V_3 - V_2 = \frac{8}{100} \times 9.43 \times 10^{-3}$$

$$V_3 - V_2 = 7.54 \times 10^{-4}\ m^3$$

$$V_3 = 7.54 \times 10^{-4} + 6.67 \times 10^{-4}$$

$$V_3 = 14.21 \times 10^{-4}\ m^3$$

$$T_3 = \frac{V_3}{V_2} \times T_2$$

$$= \frac{14.21 \times 10^{-4}}{6.67 \times 10^{-4}} \times 886.25$$

$$\boxed{T_3 = 1888.1\,K = 1615.1^\circ C}$$

Process ③ - ④

$$\frac{P_4}{P_3} = \left(\frac{V_3}{V_4}\right)^{\gamma}$$

$$P_4 = P_3 \left(\frac{V_3}{V_1}\right)^{\gamma}$$

$$= 44.31 \times \left(\frac{14.21 \times 10^{-4}}{0.01}\right)^{1.4}$$

$$\boxed{P_4 = 2.89 \text{ bar}}$$

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} \Rightarrow T_4 = T_3 \times \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$T_4 = 1888.1 \times \left(\frac{14.21 \times 10^{-4}}{0.01}\right)^{1.4-1}$$

$$= 865.53\,K = 592.53^{\circ}C$$

Cut-off ratio $= \rho = \frac{V_3}{V_2}$

$$= \frac{14.21 \times 10^{-4}}{6.67 \times 10^{-4}} = 2.13$$

(ii) Air standard efficiency:

$$\eta = 1 - \frac{1}{\gamma\, r^{\gamma-1}} \times \frac{(\rho^{\gamma} - 1)}{(\rho - 1)}$$

$$= 1 - \frac{1}{1.4 (15)^{1.4-1}} \left[\frac{2.13^{1.4} - 1}{2.13 - 1}\right]$$

$$\eta = 59.73\%$$

(iii) Mean effective pressure

$$P_m = \frac{P_1 r^{\gamma}\left[\gamma(\rho-1) - r^{1-\gamma}(\rho^{\gamma}-1)\right]}{(\gamma-1)(r-1)}$$

$$= \frac{100\times 15^{1.4}\left[1.4(2.13-1) - 15^{1-1.4}(2.13^{1.4}-1)\right]}{(1.4-1)(15-1)}$$

$= 747.66\ kN/m^2$

$P_m = 7.48$ bar

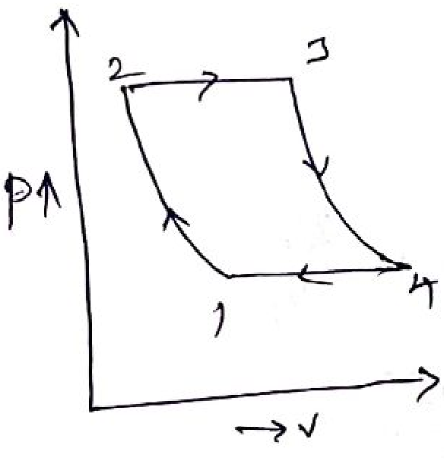
(iv) Power of the engine

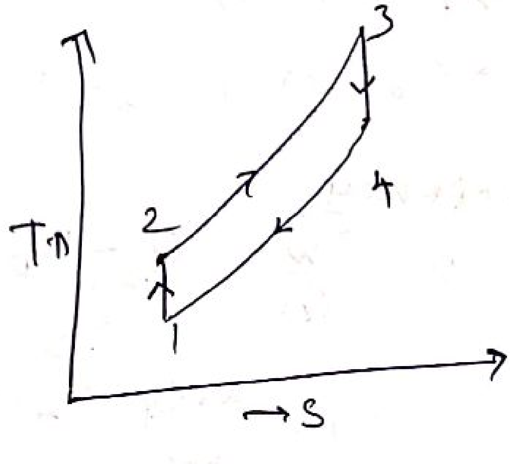
$P = P_m \times V_s \times N$

$= 747.66 \times 9.43\times10^{-3} \times \frac{380}{60}$

$P = 44.65$ KW

Brayton cycle or Joule cycle





→ Two - Isobaric process
→ Two Isentropic process
→ Application → Gas Turbine power plant

Process ① - ②

→ Isentropic Compression

→ $p\uparrow, v\downarrow, T\uparrow, S = c$

→ $r = \frac{V_1}{V_2}$, $r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4}$, $r = \frac{V_1}{V_2} = \frac{V_4}{V_3}$

Process ② - ③

→ Iso-baric Heating process

→ $P = c, V\uparrow, T\uparrow, S\uparrow$

→ $Q_s = mC_p(T_3 - T_2)$

Process ③ - ④

→ Isentropic Expansion

→ $p\downarrow, v\uparrow, T\downarrow, S = c$

Process ④ - ①

→ Iso-~~choric~~ Baric Heat rejection process

→ $P = c, T\downarrow, v\downarrow, S\downarrow$

→ $Q_R = mC_p(T_4 - T_1)$

Efficiency:

$$\eta = \frac{W}{Q_s} = \frac{Q_s - Q_R}{Q_s} = 1 - \frac{Q_R}{Q_s}$$

$$= 1 - \frac{mC_p(T_4 - T_1)}{mC_p(T_3 - T_2)}$$

$$\boxed{\eta = 1 - \frac{T_4 - T_1}{T_3 - T_2}} \quad \text{—— I}$$

From Isentropic process (1)-(2) & (3)-(4)

$$\frac{T_2}{T_1} = \frac{T_3}{T_4}$$

$$\frac{T_4}{T_1} = \frac{T_3}{T_2}$$

$$\frac{T_4}{T_1} - 1 = \frac{T_3}{T_2} - 1$$

$$\frac{T_4 - T_1}{T_1} = \frac{T_3 - T_2}{T_2}$$

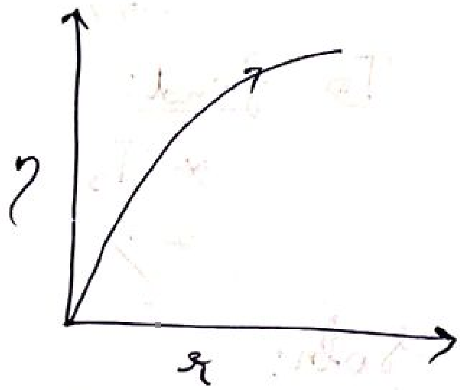
$$\frac{T_4 - T_1}{T_3 - T_2} = \frac{T_1}{T_2}$$

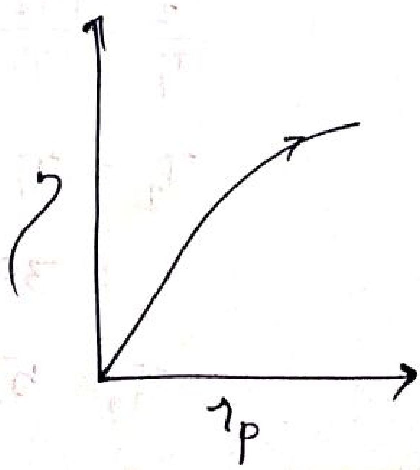
(I) → $$\eta = 1 - \frac{T_1}{T_2}$$

$$= 1 - \frac{1}{T_2/T_1}$$

$$\boxed{\eta = 1 - \frac{1}{r^{\gamma - 1}}}$$

$$\boxed{\eta = 1 - \frac{1}{r_p^{\gamma-1/\gamma}}}$$





Air enters the compressor of a gas Turbine plant operating on Brayton cycle at 1 bar, 27°C. The pressure ratio in the cycle is 6. If $W_T = 2.5 W_c$ where W_T and W_c are the turbine and compressor work respectively. Calculate the maximum Temperature and the cycle efficiency.

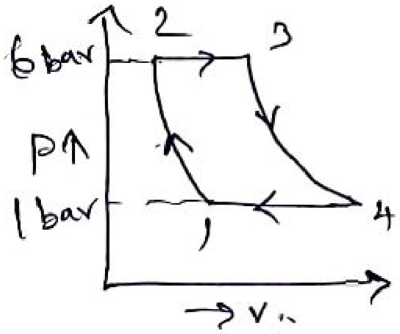
Given data:

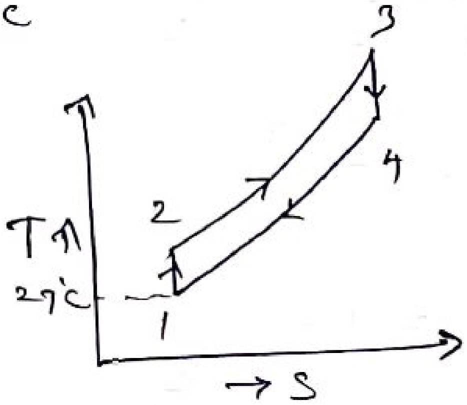
$P_1 = 1$ bar

$T_1 = 27°C = 300 K$

$R_p = 6$

$W_T = 2.5 W_c$





To find:

* T_3
* η

Soln:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (R_p)^{\gamma-1/\gamma}$$

$$T_2 = T_1 \times R_p^{\gamma-1/\gamma}$$

$$= 300 \times 6^{\frac{1.4-1}{1.4}}$$

$$T_2 = 500.55 K$$

∴ from ③ – ④

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = R_p^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_3}{T_4} = 6^{\frac{1.4-1}{1.4}} = 1.67$$

$$T_3 = 1.67\, T_4$$

$$W_T = 2.5\, W_c$$

$$C_p(T_3 - T_4) = 2.5\, C_p(T_2 - T_1)$$

$$T_3 - T_4 = 2.5\,(T_2 - T_1)$$

$$1.67 T_4 - T_4 = 2.5\,(500.55 - 300)$$

$$T_4 = 748.32\,K$$

$$T_3 = 1.67 \times 748.32$$

$$\boxed{T_3 = 1249.69\,K}$$

$$T_3 = 976.69\,^{\circ}C$$

$$\eta = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

$$= 1 - \frac{1}{6^{\frac{1.4-1}{1.4}}}$$

$$= 0.4007$$

$$\boxed{\eta_{Brayton} = 40.07\,\%}$$

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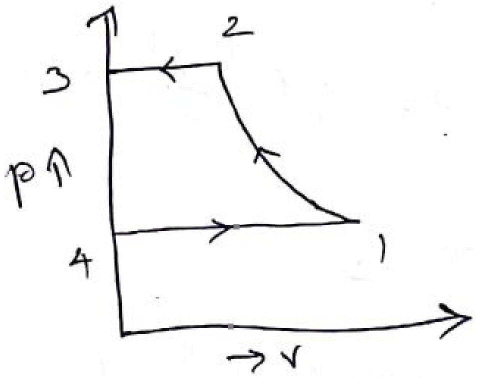
Thermal Engineering - I

① Work done by a single stage reciprocating Air compressor, without considering clearance volume

(i) Work done during Isothermal compression ($pv = c$)



process ④ - ①

* Suction of Air at P_1
* $W_1 = P(V_1 - V_4)$.
* $W_1 = P_1 V_1$

process ① - ②

* Iso-thermal compression
* $P \uparrow$, $V \downarrow$, $T = C$, $S \uparrow$
* $W_c = P_1 V_1 \ln\left(\frac{V_1}{V_2}\right)$.

process ② - ③

* Discharge of Air at P_2
* $W_2 = P_2 (V_2 - V_3)$
* $W_2 = P_2 V_2$

Work done by the Compressor

$$W = W_2 + W_c - W_1$$

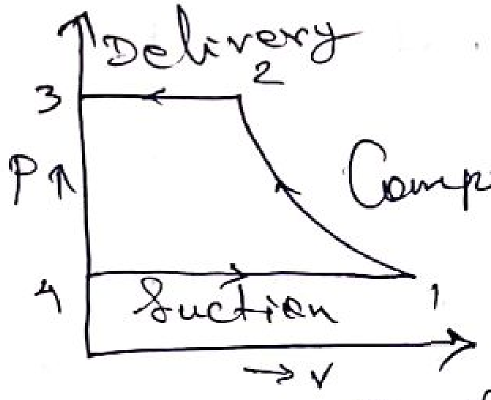
$$= P_2 V_2 + P_1 V_1 \ln\left(\frac{V_1}{V_2}\right) - P_1 V_1$$

$$= P_1 V_1 \ln\left(\frac{V_1}{V_2}\right) = P_2 V_2 \ln\left(\frac{V_1}{V_2}\right).$$

$$= mRT_1 \ln\left(\frac{V_1}{V_2}\right) = mRT_2 \ln\left(\frac{V_1}{V_2}\right)$$

$$= mRT_1 \ln\left(\frac{P_2}{P_1}\right) = mRT_2 \ln(P_2/P_1).$$

<u>Work done during polytropic Compression</u>



→ process ① - ② is polytropic process.

$$\rightarrow W = W_s + W_c + W_D.$$

$$W = \frac{P_2V_2 - P_1V_1}{n-1} + P_2V_2 - P_1V_1$$

$$= \frac{P_2V_2 - P_1V_1 + nP_2V_2 - P_2V_2 - nP_1V_1 + P_1V_1}{n-1}$$

$$= \frac{nP_2V_2 - nP_1V_1}{n-1}$$

$$W = \frac{n}{n-1}(P_2V_2 - P_1V_1) \qquad pv = mRT$$

$$= \frac{n}{n-1}[mRT_2 - mRT_1]$$

$$= \frac{n}{n-1} mR[T_2 - T_1]$$

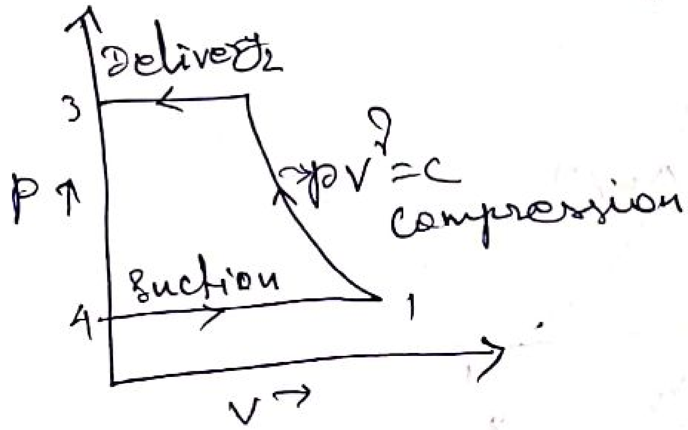
$$= \frac{n}{n-1} mRT_1 \left[\frac{T_2}{T_1} - 1\right]$$

$$\because \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$= \frac{n}{n-1} mRT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$\boxed{W = \frac{n}{n-1} P_1V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]}$$

(iii) Work done during Isentropic (or) Reversible adiabatic Compression $[pv^{\gamma} = c]$.



$$W = W_c + W_D - W_S$$

$$= \frac{P_2V_2 - P_1V_1}{\gamma - 1} + P_2V_2 - P_1V_1$$

$$= \frac{P_2V_2 - P_1V_1 + \gamma P_2V_2 - P_2V_2 - \gamma P_1V_1 + P_1V_1}{\gamma - 1}$$

$$= \frac{\gamma P_2V_2 - \gamma P_1V_1}{\gamma - 1}$$

$$= \frac{\gamma}{\gamma - 1}(P_2V_2 - P_1V_1) \qquad \because PV = mRT$$

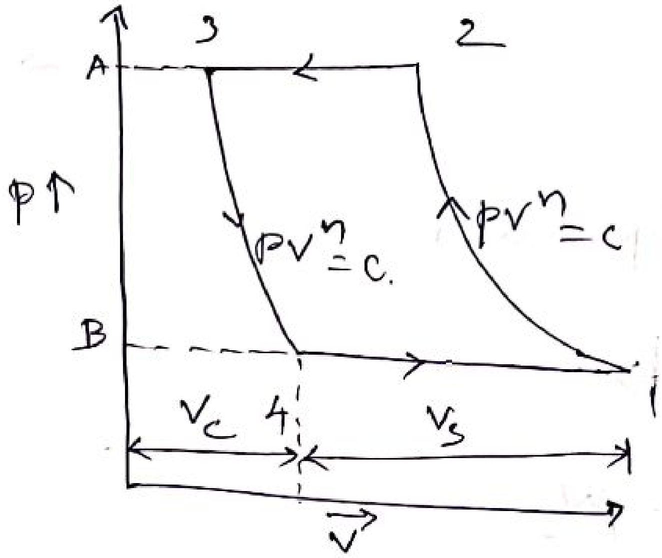
$$= \frac{\gamma}{\gamma - 1} mR(T_2 - T_1)$$

$$= \frac{\gamma}{\gamma - 1} mRT_1\left(\frac{T_2}{T_1} - 1\right) \qquad \because \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$= \frac{\gamma}{\gamma - 1} mRT_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$\boxed{W = \frac{\gamma}{\gamma - 1} P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

② Work done by single stage Reciprocating Air Compressor with clearance volume.



Take Compression is polytropic process

Work done = Area of 1-2-3-4-1

= (Area of 1-2-A-B-1) − (Area of 3-A-B-4-3).

$$\therefore W = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] - \frac{n}{n-1} P_4 V_4 \left[\left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}} - 1\right]$$

$P_1 = P_4$ & $P_2 = P_3$

$$= \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] - \frac{n}{n-1} P_1 V_4 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$W = \frac{n}{n-1} P_1 (V_1 - V_4) \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$\boxed{W = \frac{n}{n-1} P_1 V_a \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]} \quad \because V_a = V_1 - V_4$$

V_a → volume of free air Delivered

∴ In case of Isentropic process

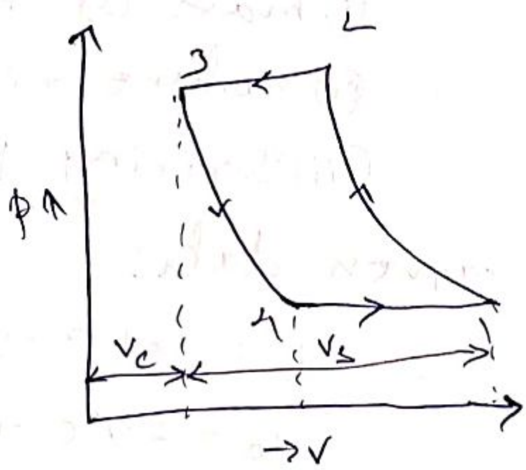
$$W = \frac{\gamma}{\gamma-1} P_1 V_a \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

(3) Volumetric Efficiency:

Volumetric efficiency is defined as the ratio of free air sucked into the compressor per cycle to the stroke volume of the cylinder.

$$\eta_{vol} = \frac{\text{volume of free air taken per cycle}}{\text{stroke volume of the cylinder}}$$

$$\eta_{vol} = \frac{V_a}{V_s}$$



$$= \frac{V_1 - V_4}{V_1 - V_3}$$

$$= \frac{V_s + V_c - V_4}{V_s + V_c - V_c}$$

$$= \frac{V_s + V_c - V_4}{V_s}$$

$$= 1 - \frac{V_4 - V_c}{V_s}$$

$$\frac{V_4}{V_3} = \left(\frac{P_3}{P_4}\right)^{1/n}$$

$$= 1 - \frac{V_c}{V_s}\left[\frac{V_4}{V_c} - 1\right]$$

$$= 1 - C\left[\left(\frac{P_3}{P_4}\right)^{1/n} - 1\right]$$

$$= 1 - C\left[\left(\frac{P_2}{P_1}\right)^{1/n} - 1\right]$$

$$\boxed{\eta_{vol} = 1 + C - C\left[\left(\frac{P_2}{P_1}\right)^{1/n}\right]}$$

(4) A single acting air compressor takes in atmospheric air [101.325 kpa, 27°C] and delivers it at 1.4 Mpa. The Compressor run at 300 r.p.m and has cylinder diameter of 160 mm and stroke of 200 mm, clearance volume 4% of stroke volume. If the pressure and temperature of air at the end of suction stroke are 100 kpa and 47°C and law of Compression and expansion is $pv^{1.2} = c$, determine the

(i) mass of the air delivered per minute

(ii) volumetric efficiency

(iii) Driving power required if $\eta_{mech} = 0.85$

Given data:

$P_0 = 101.325$ kpa

$T_0 = 27°C + 273 = 300$ k

$P_2 = 1.4$ mpa $= 1400$ kpa

$N = 300$ rpm

$D = 160$ mm $= 0.16$ m

$L = 200$ mm $= 0.2$ m

$V_c = 4\% V_s = 0.04 V_s$

$P_1 = 1$ bar $= 100$ kpa

$T_1 = 47°C = 47 + 273 = 320$ k

$n = 1.2$

$\eta_{mech} = 0.85$

To find:

* mass of air per minute
* volumetric efficiency
* driving power required if $\eta_{mech} = 0.85$

Soln:

Clearance ratio, $C = \frac{V_c}{V_s} = \frac{0.04 V_s}{V_s}$

$C = 0.04$

$\eta_{vol} = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}$

$= 1 + 0.04 - 0.04\left(\frac{1400}{100}\right)^{1/1.2}$

$\boxed{\eta_{vol} = 0.6793 = 67.93\%}$

$V_s = \frac{\pi}{4} \times D^2 \times L$

$= \frac{3.14}{4} \times 0.16^2 \times 0.2$

$= 0.00402 \, m^3$

$\eta_{vol} = \frac{V_a}{V_s}$

$V_a = \eta_{vol} \times V_s$

$= 0.6793 \times 0.00402$

$V_a = 0.00273 \, m^3$

$P_1 V_a = m R T_1$

$$m = \frac{P_1 V_a}{R T_1}$$

$$= \frac{100 \times 0.00273}{0.287 \times 320}$$

$m = 0.00297$ kg

$m' = m \times N$

$= 0.00297 \times 300$

$$\boxed{m' = 0.891 \text{ kg/min}}$$

power supply

$P = W \times$ ~~ynd~~ $\rightarrow$ kW

$$W = \frac{n}{n-1} m R T_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1 \right]$$

$$= \frac{1.2}{1.2-1} \times \frac{0.891}{60} \times 0.287 \times 320 \times \left[\left(\frac{1400}{100}\right)^{\frac{1.2-1}{1.2}} - 1 \right]$$

$$\boxed{P = 4.52 \text{ kW}}$$

Driving power

$$P_{Driving} = \frac{P_{Driven}}{\eta_{mech}}$$

$$= \frac{4.52}{0.85}$$

$$\boxed{P_{Driving} = 5.32 \text{ kW}}$$

(5.) A single stage, single acting compressor 30 cm bore and 40 cm stroke runs at 200 rpm. The suction pressure is 1 bar at 15°c and the delivery pressure 5 bar Determine the indicated mean effective pressure and ideal power required to run it, when:

(i) Compression is isothermal

(ii) Compression follows the law $pv^{1.25} = c$

(iii) Compression is reversible adiabatic $\gamma = 1.4$

Determine the isothermal efficiency for (ii), (iii) Assume $\gamma = 1.4$, $R = 0.284$ kJ/kg.k

Given data:

$D = 30\,cm = 0.3\,m$

$L = 40\,cm = 0.4\,m$

$N = 200\,rpm$

$P_1 = 1\,bar$

$T_1 = 273 + 15 = 288\,k$

$P_2 = 5\,bar$

To find:

* P_m

* Power required

* Iso thermal efficiency

Solution:

$$V_s = V_1 = \frac{\pi}{4} D^2 L$$

$$= \frac{3.14}{4} \times 0.3^2 \times 0.4$$

$$V_s = 0.0283\,m^3$$

(i) Isothermal compression

$$W = p_1 v_1 \ln\left(\frac{P_2}{P_1}\right)$$

$$= 100 \times 0.0283 \ln(5/1)$$

$$= 4.55 \text{ KJ}$$

$$P = W \times N/60$$

$$= 4.55 \times \frac{200}{60}$$

$$\boxed{P = 15.16 \text{ KW}}$$

(ii) Compression follows the law

$pv^{1.25} = C \longrightarrow n = 1.25$

$$W = \frac{n}{n-1} \times P_1 \times V_1 \times \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{1.25}{1.25-1} \times 100 \times 0.0283 \times \left[\left(\frac{5}{1}\right)^{\frac{0.25}{1.25}} - 1\right]$$

$$W = 5.373 \text{ KJ}$$

$$\text{Power} = W \times N/60$$

$$= 5.373 \times \frac{200}{60}$$

$$\boxed{\text{Power} = 17.91 \text{ KW}}$$

(iii) Isentropic Compression

$$W = \frac{\gamma}{\gamma - 1} \times P_1 \times V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$= \frac{1.4}{1.4-1} \times 100 \times 0.0283 \left[\left(\frac{5}{1}\right)^{\frac{0.4}{1.4}} - 1\right]$$

$W = 5.783\ KJ$

$$Power = W \times N/60$$

$$= 5.783 \times \frac{200}{60}$$

$$\boxed{Power = 19.28\ KW}$$

(iv) Isothermal efficiency

$$\eta_{iso\text{-}thermal} = \frac{I.P_{isothermal}}{I.P_{poly}} = \frac{15.16}{17.91}$$

$$= 0.8465$$

$$\boxed{\eta_{isothermal} = 84.65\%}$$

Iso-thermal Compression has min work input.

Indicated mean effective pressure:

(i) when compression is Iso-thermal

$$IMEP = \frac{W_{isothermal}}{V_s}$$

$$= \frac{4.55}{0.0283}$$

$$= 160.77\ Kpa$$

$$IMEP = 1.6\ bar$$

(ii) when compression is polytropic

$$IMEP = \frac{W_{poly}}{V_s}$$

$$= \frac{5.373}{0.0283}$$

$$= 189.85 \text{ kpa}$$

$$IMEP = 1.89 \text{ bar}$$

(iii) when compression is Isentropic

$$IMEP = \frac{W_{isentropic}}{V_s}$$

$$= \frac{5.783}{0.0283}$$

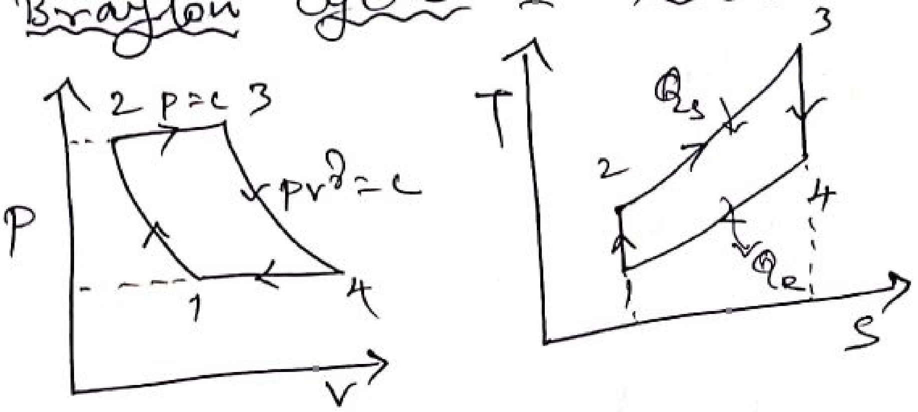
$$= 204.34 \text{ kpa}$$

$$= 2.04 \text{ bar}$$

Gas Turbines

① Derive the efficiency of Gas Turbine cycle.

Brayton cycle or Joule cycle



Process ① - ②

* Isentropic Compression
* p↑, v↓, T↑, S=c
* pressure ratio $R_p = \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = \left(\frac{T_2}{T_1}\right)^{\gamma/\gamma-1}$
* Compressor work, $W_c = m \times C_p \times (T_2 - T_3)$

Process ② - ③

* Iso-baric heating
* p=c, v↑, T↑, S↑
* $Q_s = mC_p(T_3 - T_2)$

Process ③ - ④

* Isentropic Expansion
* p↓, v↓, T↓, S=C
* $W_T = m \times C_p \times (T_3 - T_4)$
* $R_p = \frac{P_3}{P_4} = \frac{P_2}{P_1} = \left(\frac{T_3}{T_4}\right)^{\gamma/\gamma-1} = \left(\frac{V_4}{V_3}\right)^{\gamma}$

Process ④ - ①

* Iso-baric Heat Rejection

* $P = C$, $V\downarrow$, $T\downarrow$, $S\downarrow$

* $Q_R = m \times C_p \times (T_4 - T_1)$

Efficiency:

$$\eta_{Brayton} = 1 - \frac{Q_R}{Q_S}$$

$$= 1 - \frac{mC_p(T_4 - T_1)}{mC_p(T_3 - T_2)}$$

$$\boxed{\eta_{Bray} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}}$$

from ① - ② & ③ - ④ $pv^{\gamma} = c$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} ; \quad \frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\gamma-1/\gamma} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$$

$$\because \frac{T_2}{T_1} = \frac{T_3}{T_4} \Rightarrow \frac{T_4}{T_1} = \frac{T_3}{T_2}$$

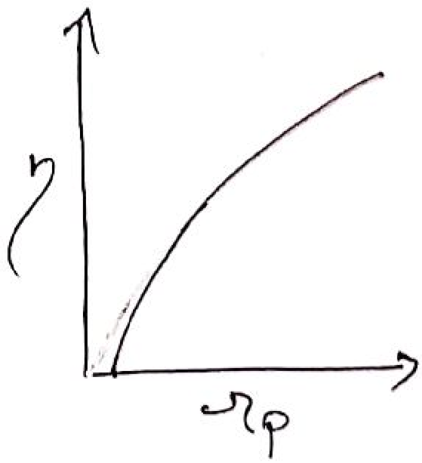
$$\frac{T_4}{T_1} - 1 = \frac{T_3}{T_2} - 1 \Rightarrow \frac{T_4 - T_1}{T_1} = \frac{T_3 - T_2}{T_2}$$

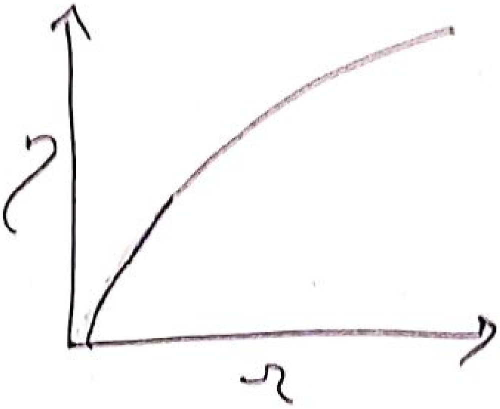
$$\frac{T_4 - T_1}{T_3 - T_2} = \frac{T_1}{T_2}$$

$$\therefore \eta = 1 - \frac{T_1}{T_2} = 1 - \frac{1}{T_2/T_1}$$

$$\boxed{\eta = 1 - \frac{1}{(r_p)^{\gamma-1/\gamma}}}$$ (pressure ratio) $\rightarrow r_p$

$$\eta = 1 - \frac{1}{r^{\gamma-1}}$$ [r - Compression ratio]





For same compression ratio the efficiency of brayton cycle is equal to the efficiency of otto cycle.

Work ratio:

The ratio of net workdone to the Turbine work

$$\text{work ratio} = \frac{\text{Net work}}{\text{Turbine work}}$$

$$= \frac{W_T - W_C}{W_T}$$

$$= \frac{mC_p(T_3 - T_4) - mC_p(T_2 - T_1)}{mC_p(T_3 - T_4)}$$

$$= 1 - \frac{T_2 - T_1}{T_3 - T_4}$$

$$= 1 - \frac{T_1 (R_p)^{\gamma-1/\gamma} - T_1}{T_3 - T_3/(R_p)^{\gamma-1/\gamma}}$$

$$= 1 - \frac{T_1\left[(R_p)^{\gamma-1/\gamma} - 1\right]}{T_3\left[1 - 1/(R_p)^{\gamma-1/\gamma}\right]}$$

$$= 1 - \frac{T_1}{T_3} \frac{1}{\frac{1}{(R_p)^{\gamma-1/\gamma}}} \times \left[\frac{(R_p)^{\gamma-1/\gamma} - 1}{(R_p)^{\gamma-1/\gamma} - 1}\right]$$

$$\left.\begin{matrix}\text{work}\\ \text{ratio}\end{matrix}\right\} = 1 - \frac{T_1}{T_3}(R_p)^{\gamma-1/\gamma}$$

(2) Explain the methods of Improving the efficiency of Brayton cycle.

(i) Brayton cycle with Regeneration

(ii) Brayton cycle with intercooling

(iii) Brayton cycle with Reheater.

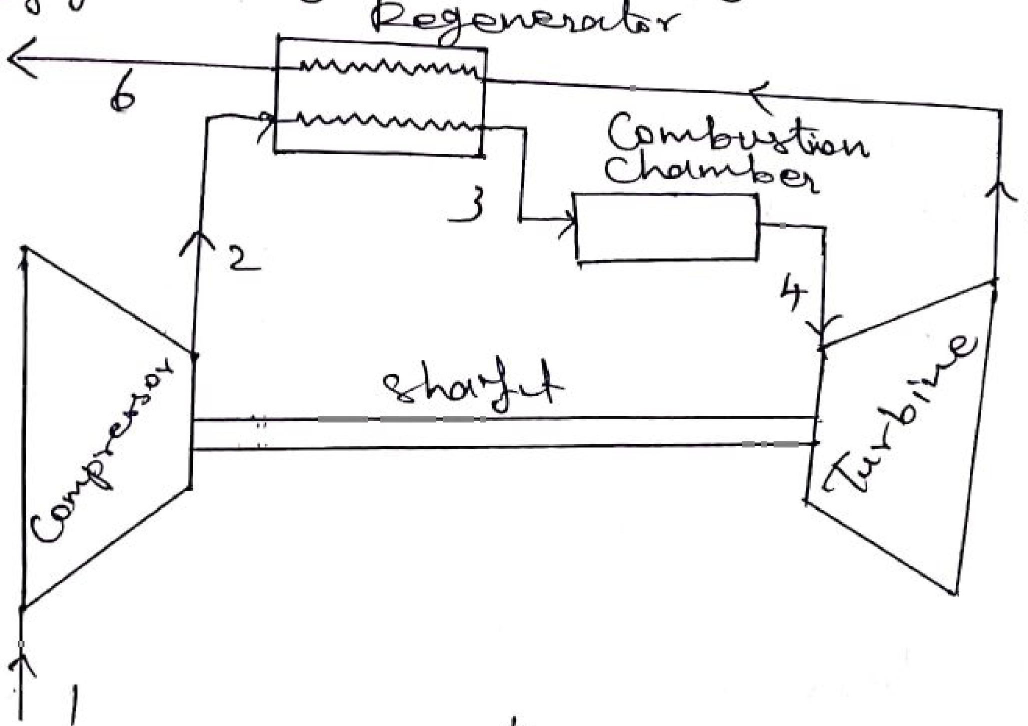
(iv) Brayton cycle with Intercooling, Reheating and Regeneration.

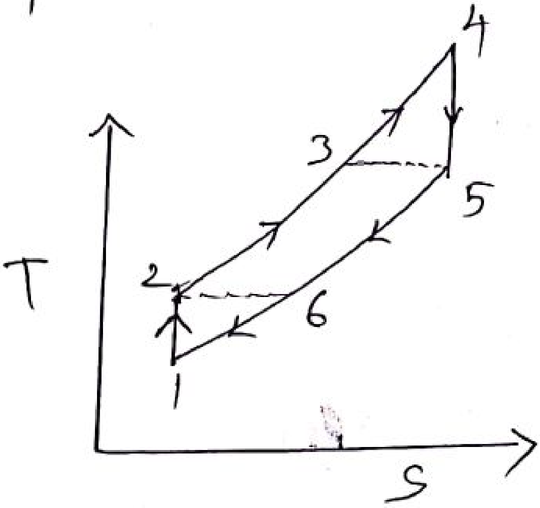
Brayton cycle with Regeneration

The temperature of exhaust gases of the turbine is higher than the temperature of the air after compression.

If the heat energy of the exhaust gases is used to preheat the Compressed air using a heat exchanger before entering into Combustion chamber. It is called regeneration.

* It will reduce the energy requirement from the fuel thereby increasing the efficiency of the cycle.





The effectiveness of the regenerator is given by the ratio of the actual temperature rise to the maximum possible rise

$$\varepsilon = \frac{T_3 - T_2}{T_5 - T_6} = \frac{T_3 - T_2}{T_5 - T_2} \quad \because T_2 = T_6$$

$$Q_S = mC_p(T_4 - T_3)$$

$$Q_R = mC_p(T_6 - T_1)$$

$$W_T = mC_p(T_4 - T_5)$$

$$W_C = mC_p(T_2 - T_1)$$

$$\eta = 1 - \frac{Q_R}{Q_S}$$

$$= 1 - \frac{T_6 - T_1}{T_4 - T_3}$$

for ideal cycle $T_3 = T_5$, $T_6 = T_2$

$$\eta = 1 - \frac{T_2 - T_1}{T_4 - T_5}$$

$$= 1 - \frac{T_1\left(\frac{T_2}{T_1} - 1\right)}{T_4\left(1 - T_5/T_4\right)}$$

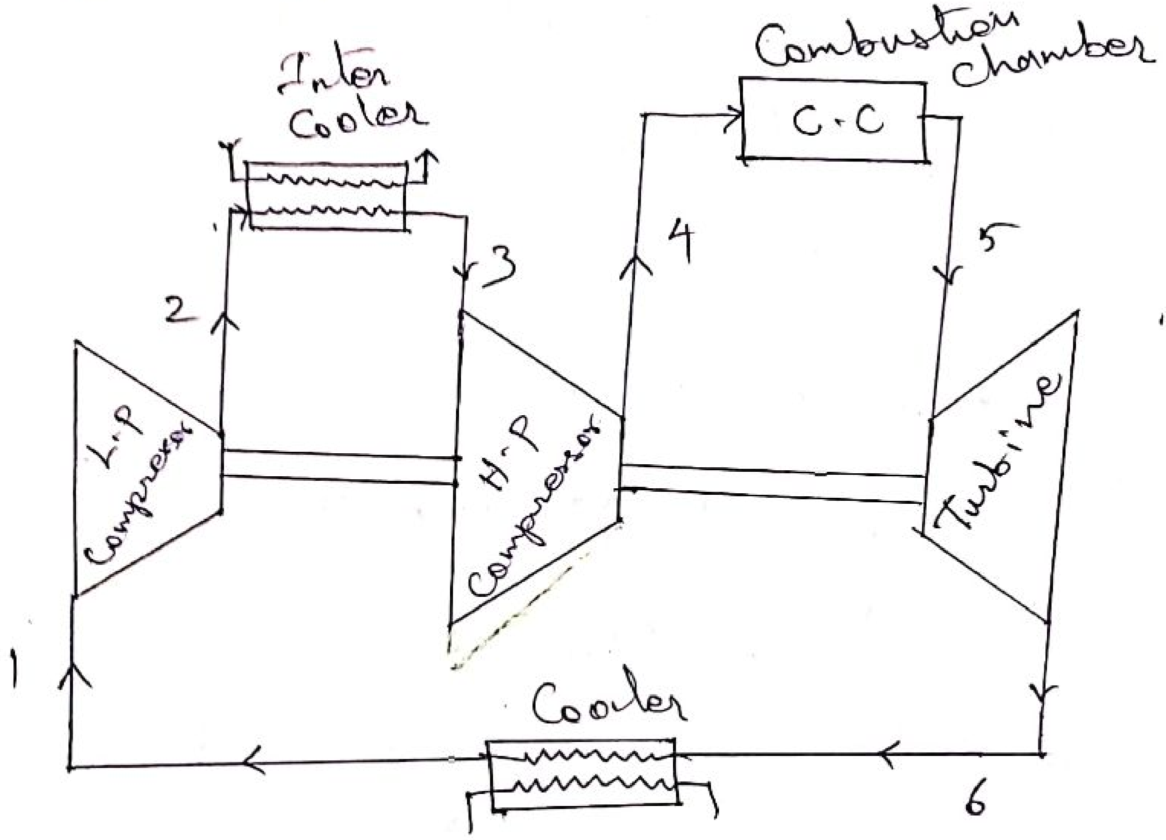
$$\frac{T_2}{T_1} = (r_p)^{\gamma-1/\gamma} \quad \frac{T_5}{T_4} = (r_p)^{\gamma-1/\gamma}$$

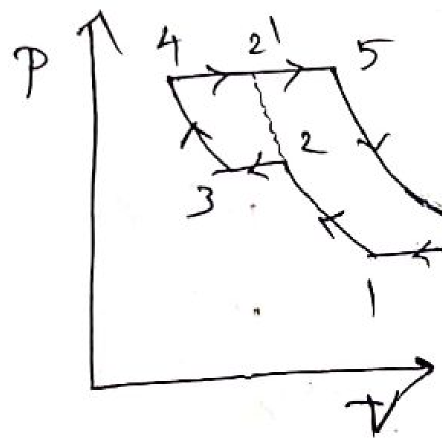
$$= 1 - \frac{T_1}{T_4}\left[\frac{(r_p)^{\frac{\gamma-1}{\gamma}} - 1}{\frac{(r_p)^{\gamma-1/\gamma} - 1}{(r_p)^{\gamma-1/\gamma}}}\right]$$

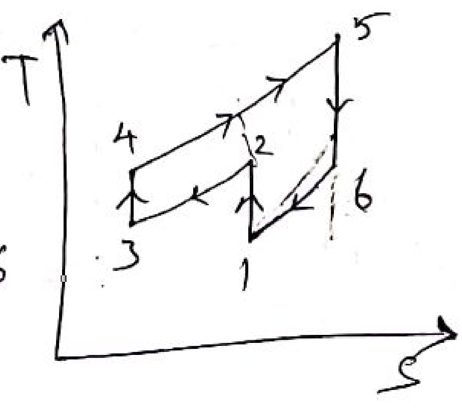
$$= 1 - \frac{T_1}{T_4}\left[\frac{r_p^{\gamma-1/\gamma} - 1}{r_p^{\gamma-1/\gamma} - 1}\right](r_p)^{\gamma-1/\gamma}$$

The efficiency of regenerative Brayton Cycle depends not only on the pressure ratio but also on the ratio of two extreme temperature.

· (i) Brayton cycle with Intercooling







* The thermal efficiency of the cycle is increased by using multi-stage air Compressor.

* work supply to the air compressor is reduced by using inter cooler

* Air enter into L.P.C and the H.P.C through the inter cooler.

* $W_T = mC_p(T_5 - T_6)$

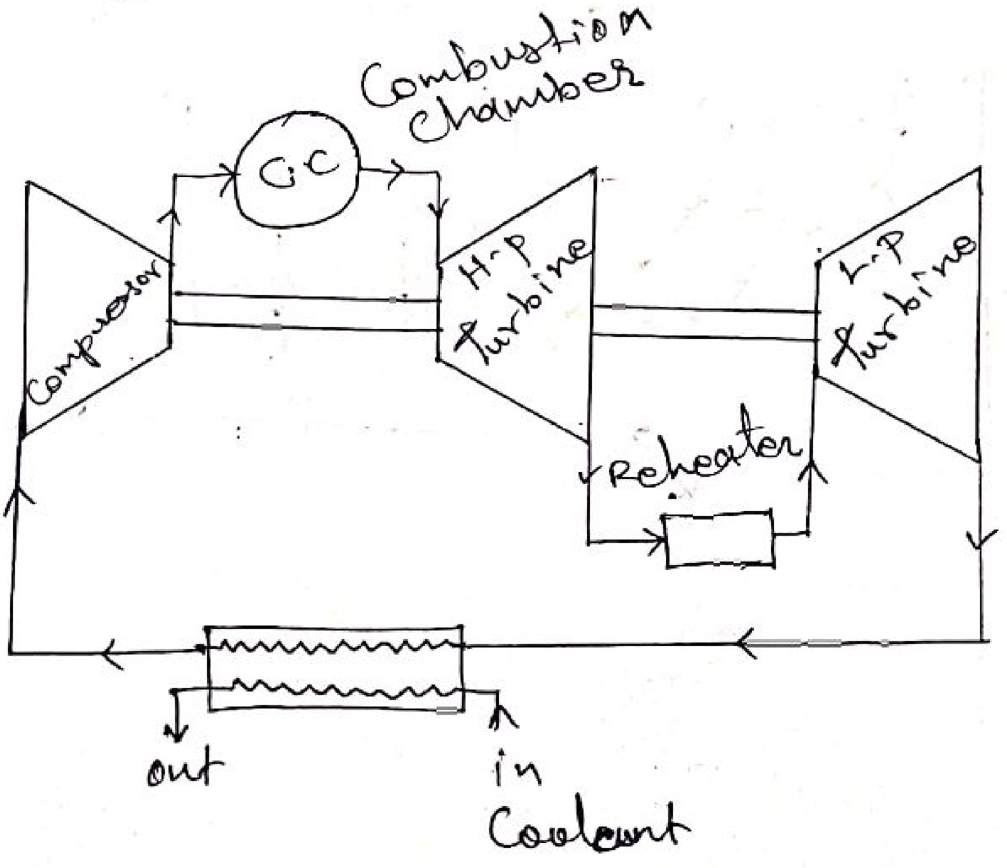
* $W_C = mC_p(T_2 - T_1) + mC_p(T_4 - T_3)$

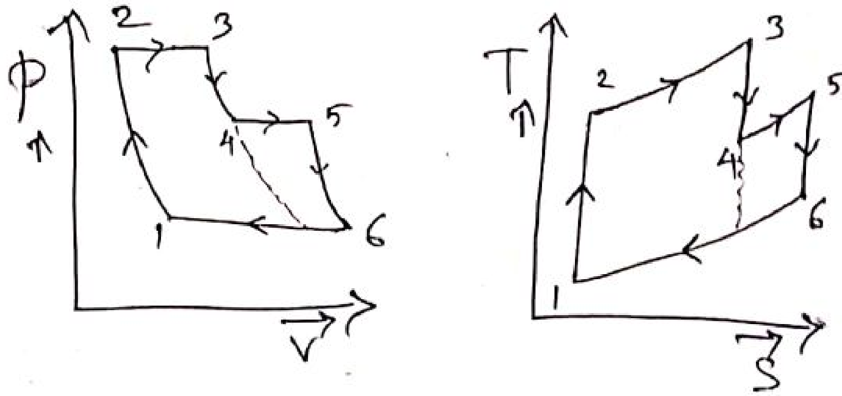
* $W_{net} = W_T - W_C$

* For perfect inter cooler $T_1 = T_3$ & $T_2 = T_4$

* $P_3 = P_2 = \sqrt{P_1 \times P_4} = \sqrt{P_5 \times P_6}$

(iii) Brayton cycle with Reheater





* The work output can be increased by multistage expansion with reheating between stages.

* Air is compressed in the compressor and passed into the combustion chamber and the to the H.P. Turbine.

* The air is once again passed into the heating chamber (reheater) and then to the second turbine.

* $W_c = m C_p (T_2 - T_1)$

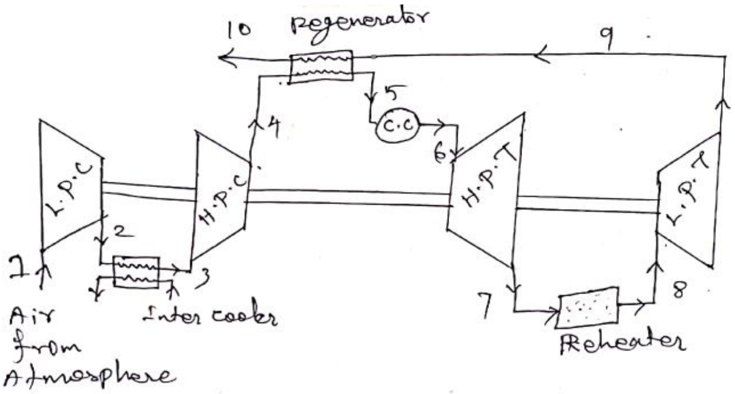
* $W_T = m C_p (T_3 - T_4) + m C_p (T_5 - T_6)$

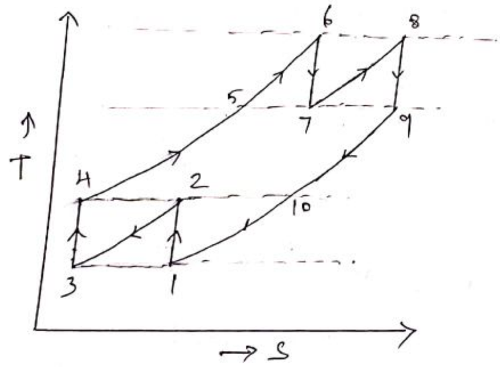
* $W_{net} = W_T - W_c$

* $P_4 = P_5 = \sqrt{P_3 \times P_6} = \sqrt{P_1 \times P_2}$ $\because P_1 = P_6$, $P_2 = P_3$

(ii) <u>Brayton cycle with Intercooling, Reheating and Regeneration</u>

* The previously stated three methods for improving the thermal efficiency of the cycle are combined together for obtaining the maximum efficiency.





* $W_c = mC_p(T_2 - T_1) + mC_p(T_4 - T_3)$
* $W_T = mC_p(T_6 - T_7) + mC_p(T_8 - T_9)$
* $W_{net} = W_T - W_c$

* $Q_s = mC_p(T_6 - T_5) + mC_p(T_8 - T_7)$
* $Q_R = mC_p(T_{10} - T_1) + mC_p(T_2 - T_3)$
* $\eta = 1 - \frac{Q_R}{Q_s}$
* $= 1 - \frac{(T_{10} - T_1) + (T_2 - T_3)}{(T_6 - T_5) + (T_8 - T_7)}$

(3) Consider an air standard cycle in which the air enters the compressor at 1.0 bar and 20°C. The pressure of air leaving the compressor is 3.5 bar and the temperature at turbine inlet is 600°C. Determine per kg of air:

(i) Efficiency of the cycle
(ii) Heat supplied to air
(iii) Work available at the shaft
(iv) Heat rejected in the cooler
(v) Temperature of air leaving the turbine.

for air $\gamma = 1.4$, $C_p = 1.005$ kJ/kg.K

Given data:

$P_1 = 1.0$ bar
$T_1 = 20 + 273 = 293$ K
$P_2 = 3.5$ bar
$T_3 = 600 + 273 = 873$ K
$\gamma = 1.4$, $C_p = 1.005$ kJ/kg.K

To find:

* η
* Q_S
* W
* Q_R
* T_4

Solution:

(i) Efficiency

$$\eta = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

$$r_p = \frac{P_2}{P_1} = 3.5$$

$$= 1 - \frac{1}{(3.5)^{\frac{1.4-1}{1.4}}}$$

$$= 0.30$$

$$\boxed{\eta = 30\%}$$

(ii) Heat supplied to air

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{3.5}{1}\right)^{\frac{1.4-1}{1.4}}$$

$$\frac{T_2}{T_1} = 1.43$$

$$T_2 = 293 \times 1.43$$

$$T_2 = 419 k$$

$$Q = C_p (T_3 - T_2)$$

$$= 1.005 (873 - 419)$$

$$\boxed{Q = 456.27 \ kJ/kg}$$

(iii) Work available at the shaft

$$\eta_{cycle} = \frac{\text{work done}}{\text{Heat supply}}$$

$$0.3 = \frac{W}{456.27}$$

$$W = 0.3 \times 456.27$$

$$\boxed{W = 136.88 \ kJ/kg}$$

(iv) Heat rejected in the cooler Q_R

$$W = Q_S - Q_R$$

$$Q_R = Q_S - W$$

$$= 456.27 - 136.88$$

$$\boxed{Q_R = 319.39 \ kJ/kg}$$

(v) Temperature of air leaving the Turbine

$$\frac{T_3}{T_4} = (r_p)^{\frac{\gamma-1}{\gamma}} = (3.5)^{\frac{1.4-1}{1.4}} = 1.43$$

$$T_4 = \frac{T_3}{1.43} = \frac{873}{1.43}$$

$$\boxed{T_4 = 610.5 \ k}$$

(4) In a gas Turbine plant working on Brayton cycle, the air at inlet is 27°C, 0.1 mpa. The pressure ratio is 6.25 and the maximum temperature is 800°c. The turbine and compressor efficiencies are each 80%. Find compressor work, turbine work, heat supplied, cycle efficiency and turbine exhaust temperature

mass of air may be considered as 1kg. Draw T-s diagram.

Given data:

$T_1 = 27°C = 300k$

$p_1 = 0.1 MPa = 1 bar$

$r_p = 6.25$

$T_3 = 800°C = 1073k$

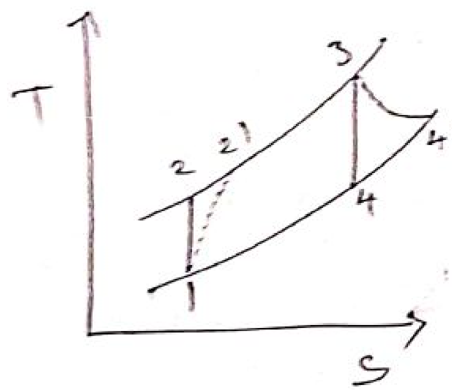
$\eta_c = \eta_T = 0.8$

$m = 1 kg$

To find:

* W_c
* W_t
* Q_s
* η
* T_4

Solution:



Sol.

$r_p = 6.25$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$= (6.25)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 1.688 \times T_1 = 300 \times 1.688$$

$$T_2 = 506.4k$$

$$\eta_c = 0.8 = \frac{T_2 - T_1}{T_2' - T_1} = \frac{506.4 - 300}{T_2' - 300}$$

$$T_2' = \frac{506.4 - 300}{0.8} + 300$$

$$\boxed{T_2' = 558k}$$

$$W_c = m C_p (T_2' - T_1)$$

$$= 1 \times 1.005 (558 - 300)$$

$$\boxed{W_c = 259.29 \ kJ/kg}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$= (6.25)^{\frac{1.4-1}{1.4}} = 1.688$$

$$T_4 = \frac{T_3}{1.688}$$

$$= \frac{1027}{1.688}$$

$$\boxed{T_4 = 635.66k}$$

$$\eta_T = \frac{T_3 - T_4'}{T_3 - T_4}$$

$$0.8 = \frac{1073 - T_4'}{1073 - 635.66}$$

$$T_4' = 1073 - 0.8(1073 - 635.66)$$

$$\boxed{T_4' = 723.13k} = 450.13^\circ C$$

$$W_T = m C_p (T_3 - T_4')$$

$$= 1 \times 1.005 (1073 - 723.13)$$

$$\boxed{W_T = 351.6 \, kJ/kg}$$

$$W_{net} = W_T - W_C$$

$$= 351.6 - 259.29$$

$$\boxed{W_{net} = 92.31 \, kJ/kg}$$

$$Q_s = m C_p (T_3 - T_2')$$

$$= 1 \times 1.005 (1073 - 558)$$

$$\boxed{Q_s = 517.57 \, kJ/kg}$$

$$\eta = \frac{W_{net}}{Q_s} = \frac{92.31}{517.57}$$

$$\boxed{\eta = 17.83\%}$$

⑤ Air is drawn in a gas turbine unit at 15°c and 1.01 bar and pressure ratio is 7:1. The compressor is driven by the H.P. Turbine and L.P. Turbine drives a separate power shaft. The isentropic efficiencies of compressor, and H.P and L.P. Turbine are 0.82, 0.85 and 0.85 respectively. If the maximum cycle temperature is 610°C, Calculate:

(i) The pressure and temperature of the gases entering the power turbine.

(ii) The net power developed by the unit mass flow

(iii) The work ratio

(iv) The thermal efficiency of the unit

Neglect the mass of fuel and assume the following

for Compression $C_{pa} = 1.005 \, kJ/kg.k$ & $\gamma = 1.4$

for combustion & expansion $C_{pg} = 1.15 \, kJ/kg.k$, $\gamma = 1.333$

Given data:

$T_1 = 15 + 273 = 288k$

$p_1 = 1.01$ bar

$r_p = 7$

$\eta_c = 0.82$

$\eta_{H.P.T} = \eta_{L.P.T} = 0.85$

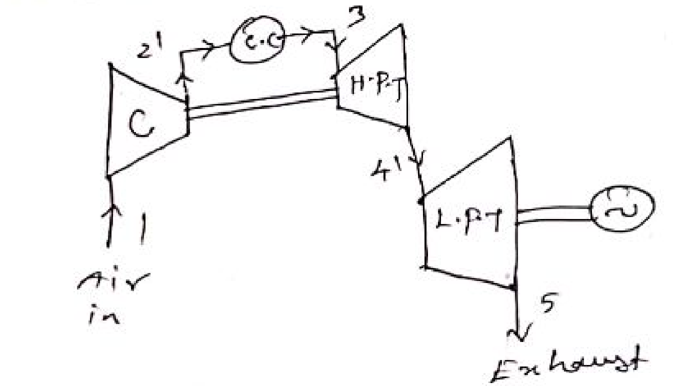
$C_{pa} = 1.005$ kJ/kg.K, $\gamma = 1.4$

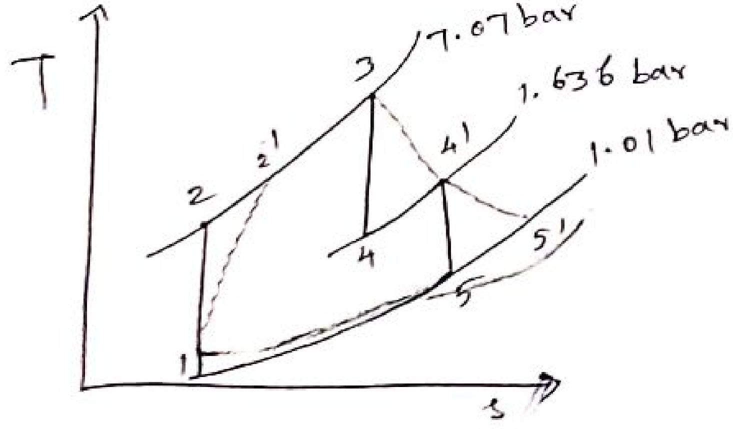
$C_{pg} = 1.15$ kJ/kg.K, $\gamma = 1.333$

To find:

* P_4' & T_4'
* power output
* work ratio
* η

Solution:





(1) Pressure and Temperature of the gases entering the power turbine

$$\frac{T_2}{T_1} = (r_p)^{\frac{\gamma-1}{\gamma}} = (7)^{\frac{1.4-1}{1.4}} = 1.745$$

$$T_2 = 288 \times 1.745 = 502.5\,K$$

$$\eta_c = \frac{T_2 - T_1}{T_2' - T_1}$$

$$0.82 = \frac{502.5 - 288}{T_2' - 288}$$

$$T_2' = \frac{502.5 - 288}{0.82} + 288$$

$$\boxed{T_2' = 549.6\,K}$$

$$W_c = C_p(T_2' - T_1)$$

$$= 1.005(549.6 - 288)$$

$$W_c = 262.9\ \text{kJ/kg}$$

$$W_c = W_{H.P.T} = 262.9\ \text{kJ/kg}$$

$$C_{pg}(T_3 - T_4') = 262.9$$

$$1.15(883 - T_4') = 262.9$$

$$T_4' = 883 - \frac{262.9}{1.15}$$

$$\boxed{T_4' = 654.4\,K}$$

$$\eta_{H.P.T} = \frac{T_3 - T_4'}{T_3 - T_4}$$

$$0.85 = \frac{883 - 654.4}{883 - T_4}$$

$$T_4 = 883 - \left(\frac{883 - 654.4}{0.85}\right)$$

$$\boxed{T_4 = 614\,K}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \left(\frac{T_3}{T_4}\right)^{\gamma/\gamma-1}$$

$$= \left(\frac{883}{614}\right)^{\frac{1.33}{0.33}} = 4.32$$

$$P_4 = \frac{P_3}{4.32} = \frac{7.07}{4.32}$$

$$\boxed{P_4 = 1.636\ bar}$$

Net power developed per kg/s

$$\frac{P_4}{P_5} = \frac{P_4}{P_3} \times \frac{P_3}{P_5}$$

$$\frac{P_4}{P_5} = \frac{P_4}{P_3} \times \frac{P_2}{P_1} \qquad \frac{P_4}{P_3} = \frac{1}{4.32}, \frac{P_2}{P_1} = 7$$

$$= \frac{7}{4.32}$$

$$\frac{P_4}{P_5} = 1.62$$

$$\frac{T_4'}{T_5} = \left(\frac{P_4}{P_5}\right)^{\gamma-1/\gamma} = (1.62)^{\frac{0.33}{1.33}} = 1.127$$

$$T_5 = \frac{T_4'}{1.127} = \frac{654.4}{1.127}$$

$$T_5 = 580.6\,K$$

$$\eta_{L.P.T} = \frac{T_4' - T_5'}{T_4' - T_5} = 0.85$$

$$0.85 = \frac{654.4 - T_5'}{654.4 - 580.6}$$

$$T_5' = 654.4 - 0.85(654.4 - 580.6)$$

$$\boxed{T_5' = 591.7\,K}$$

$$W_{L.P.T} = C_{pg}(T_4' - T_5')$$

$$= 1.15(654.4 - 591.7)$$

$$W_{L.P.T} = 72.1\ KJ/kg$$

$$\boxed{P = 72.1\ KW} \qquad \because P = W \times \dot{m},\ \dot{m} = 1\ kg/s$$

work ratio

$$= \frac{W_{net}}{W_{gross}} = \frac{72.1}{72.1 + 262.9}$$

$$\boxed{\text{work ratio} = 0.215}$$

Efficiency:

$$\eta = \frac{W_{net}}{Q_s}$$

$$Q_s = C_{pg}(T_3 - T_2')$$

$$= 1.15(883 - 549.6)$$

$Q_s = 383.4$ kJ/kg

$$\eta = \frac{72.1}{383.4}$$

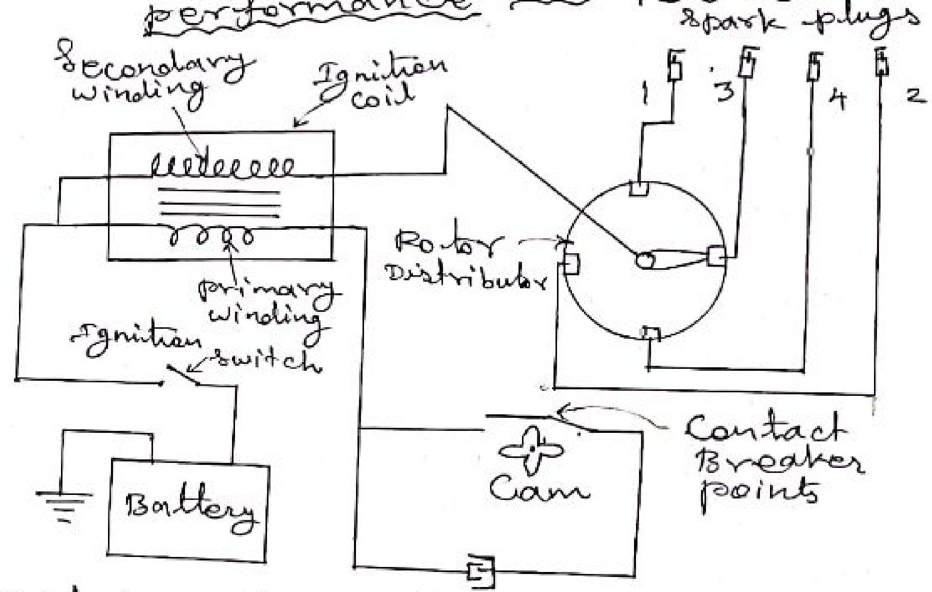
$= 0.188$

$\boxed{\eta = 18.8\%}$

II yr mech Thermal Engineering-I

Unit-IV

Internal Combustion engine performance and systems



① Explain Battery (or) Condenser Coil ignition system with sketch.

Construction

* It consists of a battery, ignition coil, Condenser, contact breaker, distributor and spark plugs.

* 6 or 12 volts battery is used

* The ignition Coil consists of two windings primary and secondary

* The primary winding consists of a thick wire with less number of turns The primary winding is formed of 200-300 turns of thick wire of #20-gage to produce a resistance

of about 1.5 ohms.

* The secondary winding located inside the primary winding consists of 21,000 turns of thin enamelled wire of #38-40 gages with sufficiently insulated to withstand high voltage.

* The distributor distributes the high voltage to the respective spark plugs having regular intervals in the sequence of firing order of the engine

* The sequence in which the firing or power occurs in a multi-cylinder engine is known as firing order.

* The firing order of a 4-cylinder inline engine is 1-3-4-2.

Working:

The ignition switch is switched on when the engine is cranked. The cranking of the engine opens and closes the contact breaker points through a cam.

When the contact breaker points are closed.

* The current flows from the battery, to the contact breaker points through the switch and primary winding and then it returns to a battery through the earth.

* This current builds up a magnetic field in the primary winding of the ignition coil.

* When the primary current is at the highest peak, the contact breaker points will be opened by the cam

When the contact breaker points are opened:

* The magnetic field sets up in the primary winding which is suddenly collapsed.

* A high voltage (15000 volts) is generated in the secondary winding of the ignition coil.

* This high voltage is directed to the rotor of the distributor.

* The rotor directs this high voltage to the individual spark plugs in the sequence of the firing order of the engine.

* This high voltage tries to cross the spark plug gap (0.45 to 0.6mm) and the spark is produced. This spark

- Ignites the fuel-air mixture.

Advantages:

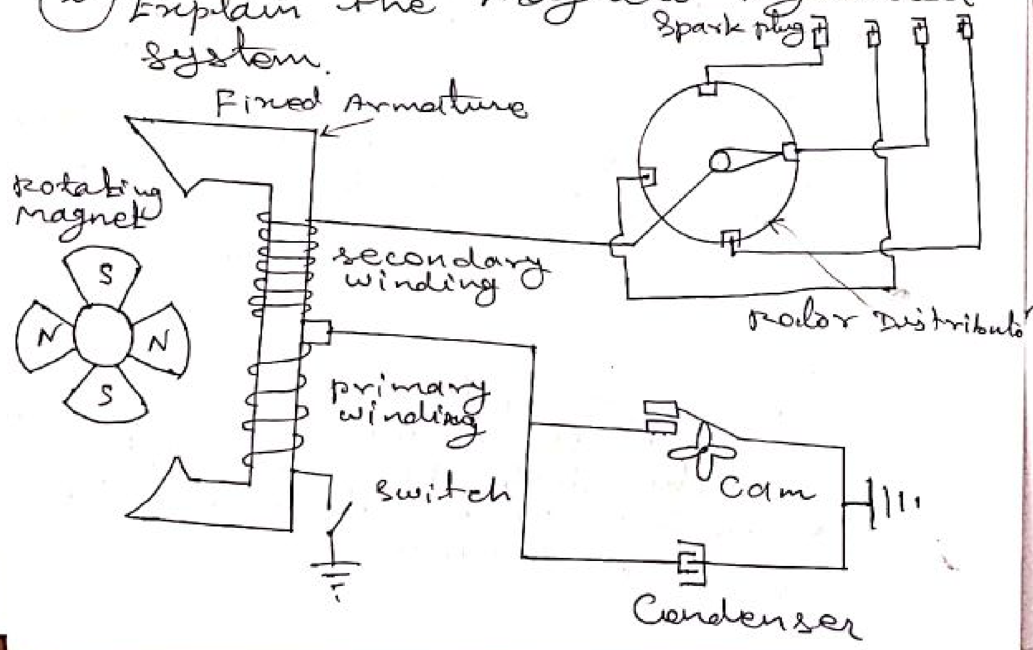
* It provides better sparks at low speeds of the engine during starting and idling due to the availability of maximum current throughout the engine speed range.

* The initial cost is low as compared with magneto ignition system.
* The maintenance cost is negligible except the battery.
* Spark efficiency remains unaffected by various positions of the timing control mechanism.

Disadvantages:

* Frequent battery down occurs when the engine is not in use continuously. It causes a starting trouble.
* The weight is greater than magneto ignition system.
* Wiring mechanism is more complicated.

(2) Explain the magneto Ignition system.



* In this system, the battery is replaced with a magneto.
* It consists of a switch, magneto, contact breaker, condenser, distributor and spark plugs.
* This system is used in two wheelers such as motor cycles, scooters

Construction:

* The magneto ignition system consists of a rotating magnet assembly driven by an engine and a fixed armature.
* The armature consists of primary and secondary windings
* The primary circuit consists of a primary winding, condenser and contact breaker.
* The secondary circuit consists of secondary windings, distributor and spark plugs.

When the contact breaker points are closed

* The current flows in the primary circuit.
* It produces a magnetic field in the primary windings
* When the primary current is at the highest peak, the contact breaker points will be opened by the cam.

When the contact breaker points are opened:

* There is a break in the primary circuit
* The magnetic field in the primary winding is suddenly collapsed.
* A high voltage (15000V) is generated in the secondary winding.
* This high voltage is distributed to the respective spark plugs through the rotor of the distributor.
* The high voltage tries to cross the spark plug gap and a spark is produced in the gap. This spark ignites the fuel-air mixture in the engine cylinder.

Advantages:

* It has no maintenance problem
* when the speed increase, it provides a better intensity of spark.
* Less space is required as compared to battery ignition system.
* It is light in weight and compact in size.