Ideal Cycle of IC Engine

The following operation are common for all the ideal cycle of I.C. engine

* HP only const vol. पर होता है only
* HA const V & P पर होता है only

① Reversible and adiabatic expansion.

② Heat rejection at constant Volume.

③ Reversible and adiabatic compression.

It is thus clear it is only the heat addition will be different for the different cycle.

→ when ~~the~~ HA takes place at constant Volume. the cycle is know as constant volume cycle or otto cycle.

→ When HA takes place at constant pressure, the cycle is know as constant pressure cycle or diesel cycle.

→ In another cycle when the HA takes place, 1st at const. volume and than at const. pressure, the cycle is know as the dual combustion cycle or semi diesel cycle.

Working of a Costant ~~Voolume~~ or Otto Cycle :-

① The adiabatic Compression process 1-2

$V\downarrow,\ P\uparrow,\ T\uparrow,\ S$ is Constant $(S=C)$

② The Constant Volume Heat addition process 2-3

$V=C,\ P\uparrow,\ T\uparrow,\ S\uparrow$ $\left\{ \overset{+}{ds} = \frac{dQ \rightarrow +}{T} \right.$

$(S_2-S_1)>0$

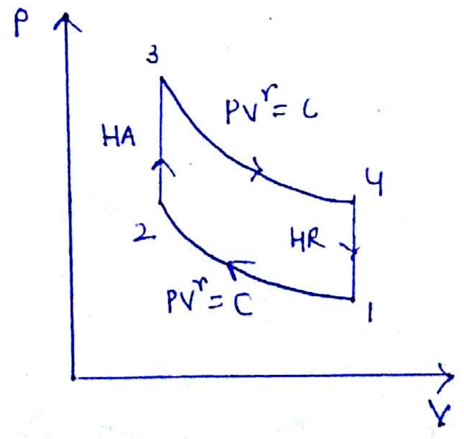
③ The adiabatic expansion process 3-4

$V\uparrow,\ P\downarrow,\ T\downarrow,\ S=C$ $\left\{ \begin{array}{l} dQ = 0 \\ ds = \text{Constant}) \end{array} \right.$

④ The constant volume Heat Rejection process 4-1

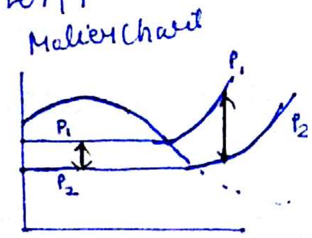
$V=C,\ P\downarrow,\ T\downarrow,\ S$ dec$(\downarrow)$

P-V diagram



* 1-2 & 3-4 slopes are different

Proof

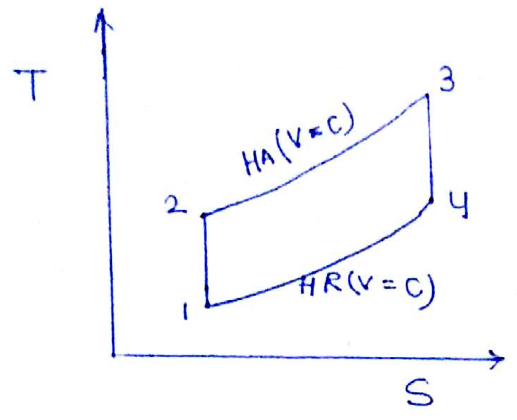


Steam table

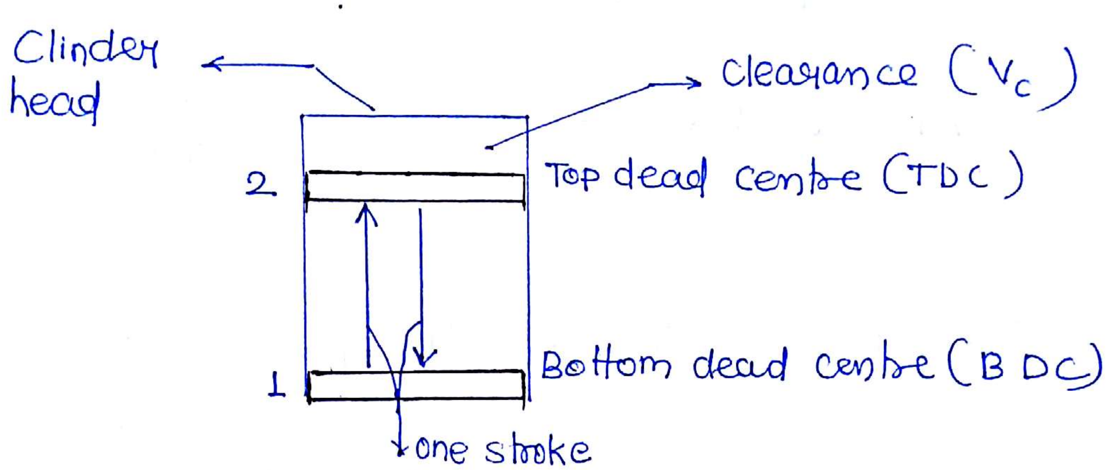
	P	V	
2	12	0.073	0.022
	10	0.095	
2	3	0.96	0.77.
	1	1.73	

at same P diff move V diff.

T-S diagram



General information about IC Engine



- length is stroke length (L)
- Vol. covered is stroke Vol. or swept Vol. (V_s)

Clearance:- it is the space between the TDC and cylinder head. The volume occupied by the clearance space is ~~eta~~ called Clearance Volume (V_c)

⇒ For any process $\boxed{\text{Volume Ratio} = \dfrac{\text{large Volume}}{\text{less Volume}}}$

⇒ The volume ratio during expansion process called expansion ratio. This ratio is diff. for different cycle,

⇒ The volume ratio during Compression is called Compression Ratio.

The expression for compression ratio is same for all the cycle and is Given by

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

$$V_2 = V_c$$

$$\therefore \quad \boxed{r = \frac{V_c + V_s}{V_c}} \quad \text{or} \quad \boxed{r = 1 + \frac{V_s}{V_c}} \quad \text{or} \quad \boxed{\frac{V_s}{V_c} = (r-1)}$$

Efficiency $\quad \eta_v = \frac{WD}{HA} = \frac{HA - HR}{HA} = 1 - \frac{HR}{HA}$

For otto cycle

$$HA = mc_v(T_3 - T_2)$$

बाद वाले temp को पहले रखना है हमेशा

$$HR = -dQ = -mc_v(T_1 - T_4)$$

$$= mc_v(T_4 - T_1)$$

$$\eta_v = 1 - \frac{mc_v(T_4 - T_1)}{mc_v(T_3 - T_2)} \quad \text{— (a)}$$

$$\text{or} \quad \eta_v = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

From P-V diagram

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

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

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

This is also equal to

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

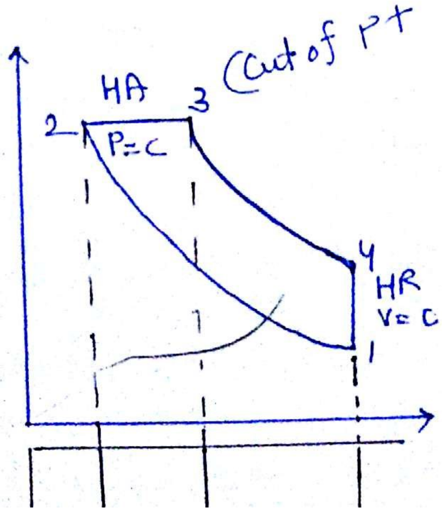
So Efficiency of otto cycle

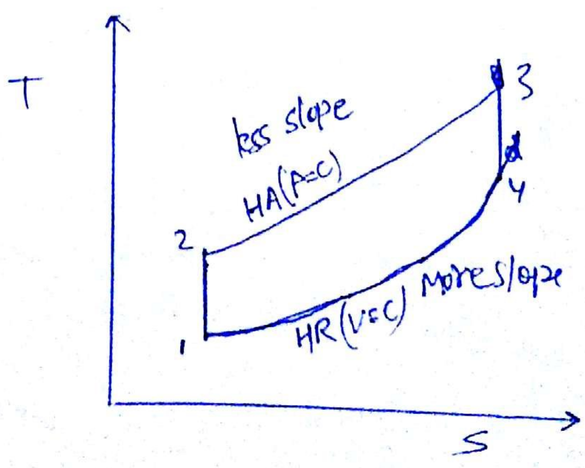
$$\boxed{\eta_v = 1 - \left(\frac{1}{\gamma}\right)^{r-1}}$$

{r - depandand on supstance (Gas)}

20/Aug/2016

The Diesel Cycle or the Constant Pressure Cycle.





let $r = \frac{V_1}{V_2}$, the Comp. Ratio

& $\rho = \frac{V_3}{V_2}$, the cutoff Ratio

exp. ratio $= \frac{V_4}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3} = \frac{r}{\rho}$

1-2

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

2-3

$$\rho = \frac{V_3}{V_2} = \frac{T_3}{T_2} \Rightarrow \therefore T_3 = T_2 \rho$$

$$T_3 = T_1 r^{\gamma-1} \rho \quad - (2)$$

3-4

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

$$\therefore T_4 = T_3 \left(\frac{\rho}{r}\right)^{\gamma-1} \quad \therefore T_4 = T_1 r^{\gamma-1} \cdot \rho \left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$T_4 = T_1 \rho^{\gamma} \quad - (3)$$

$$\eta_p = 1 - \frac{HR}{HA}$$

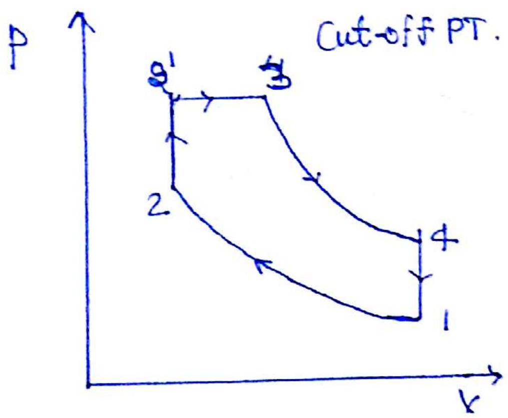
$$\eta_p = 1 - \frac{mC_v(T_4 - T_1)}{mC_p(T_3 - T_2)}$$

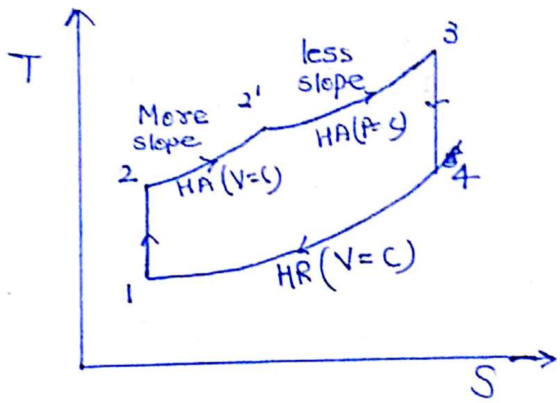
$$\eta_p = 1 - \frac{1}{\gamma} \frac{T_1 \rho^{\gamma} - T_1}{T_1 r^{\gamma-1} \rho - T_1 r^{\gamma-1}}$$

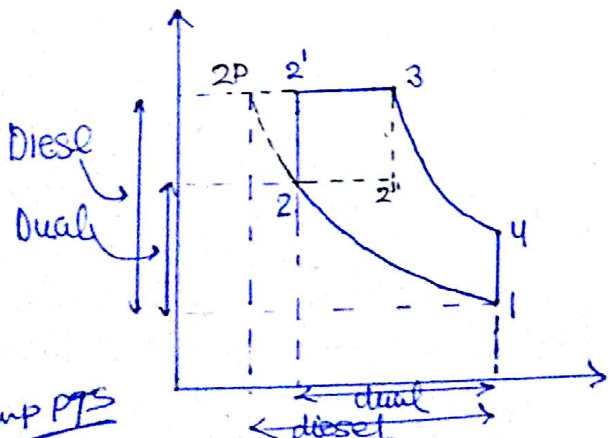
$$\boxed{\eta_p = 1 - \left(\frac{1}{r}\right)^{\gamma - 1} \frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}}$$

$$\boxed{\eta_p = 1 - \left(\frac{1}{r}\right)^{\gamma - 1} \frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}}$$

Dual Combustion Cycle or Semi-Diesel Cycle :-







* diesel cycle में stroke length ज्यादा होगी तो sound ज्यादा आयेगा space भी ज्यादा लेगा
* efficiency diesel cycle की ज्यादा होती है for same peak P.

Imp PTS

1. For a dual cycle, the heat addition takes place first at constant volume and than at constant pressure.
2. If the heat addition takes place first at Const. P and than at const. V, the efficiency of

cycle is reduce. Beside, the piston has to stop in middle of it's motion for constant Vol. heat addition which is not possible in practice.

③ If heat addition for constant Volume ~~pressure is~~ process is more than, higher pressure can be increase in that case the cylinder may explose. If the lower pressure is decrease, the compression ratio will be lesser for the cycle the efficiency of cycle will be much reduced, Thus ~~the~~ for safe condⁿ and higher efficiency of cycle, the HA during constant Volume process will much less.

④ For a higher efficiency of the cycle, the ~~HA~~ heat added at const. pressure is 2-3 times more than the heat added at const. Volume.

⑤ The ratio of pressure during the const. volume HA process is know as the explosation ratio. (in the fig. the explosation ratio is $\alpha = \frac{P_2'}{P_2}$)

⑥ The efficiency of the diesel cycle is higher than that of the dual cycle. Due to it's higher compression ratio.

⑦ For the diesel cycle, $r = 16$ to 20

For the dual cycle, $r = 12$ to 16.

For the otto cycle $r = 6$ to 12

(8) Due to lesser Comp. ratio, the dual cycle ~~of~~ engine is more compact in size and can be thus use for smaller vehicles also.

(9) The sound population for a diesel cycle engine is much higher than that of the dual cycle engine.

(10) Due compact size of dual cycle engine, the maintainance is easier for this engine than that of the diesel cycle engine. Besides the maintenance Cost of dual cycle engine is also much less.

Efficiency of Dual Cycle:-

let $\frac{P_2'}{P_2} = \alpha$, the expansion Ratio

& $r = \frac{V_1}{V_2}$ Compression ratio

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

The expansion ratio is $\frac{V_4}{V_3} = \frac{V_1}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3} = \frac{r}{\rho}$

1-2

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

2-2'

V=C $$\frac{T_2'}{T_2} = \frac{P_2'}{P_2} = \alpha \quad \therefore T_2' = T_2\alpha = T_1 r^{\gamma-1}\alpha \quad -(2)$$

2'-3

P=C $$\frac{T_3}{T_2'} = \frac{V_3}{V_2'} = \frac{V_3}{V_2} = \rho \Rightarrow T_3 = T_2'\rho$$

$$T_3 = T_1 r^{\gamma-1}\rho\alpha \quad -(3)$$

3-4

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} \quad \therefore T_4 = T_1 r^{\gamma-1}\alpha\rho\left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$\therefore T_4 = T_1\alpha\rho^{\gamma}$$

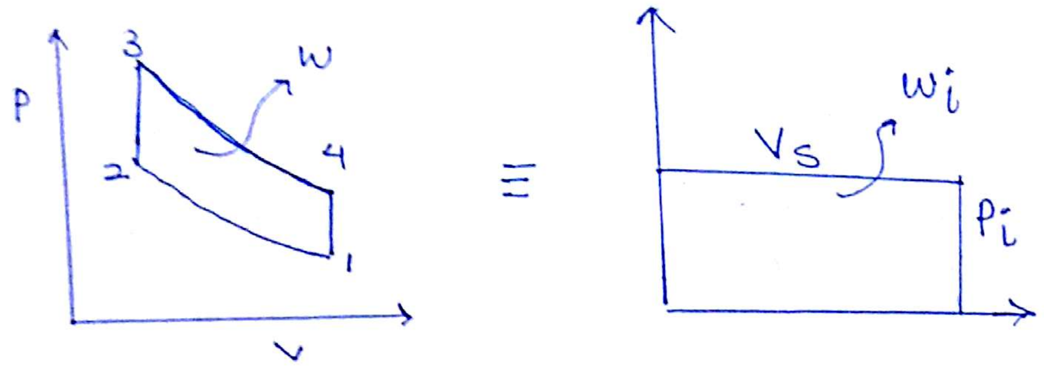
$$\eta_s = 1 - \frac{HR}{HA} = 1 - \frac{mc_v(T_4 - T_1)}{mc_v(T_2' - T_2) + mc_p(T_3 - T_2')}$$

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

$$\boxed{\eta_s = 1 - \left(\frac{1}{r}\right)^{\gamma-1}\frac{\alpha\rho^{\gamma} - 1}{\alpha\gamma(\rho-1) + (\alpha-1)}}$$

Mean Effective Pressure:- (P_m or mep)

When we consider an imaginary pressure which when remaining Costant will give us same work done for the same change in Volume like that of the actual cycle, than the ~~img~~ imaginary Constant pressure is know as mean effective pressure of cycle



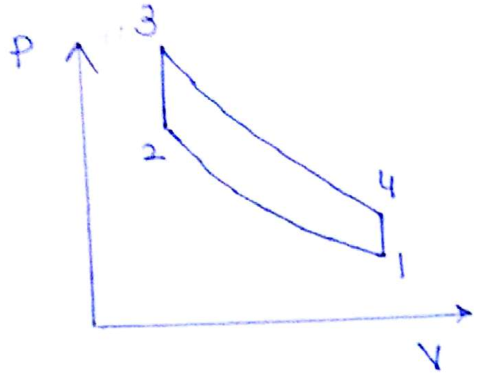
$$W_i = P_i \times V_s = A \Rightarrow \text{when } W_i = W, \; P_i = P_m$$

$$W = P_m \times V_s$$

* The work done for the cycle by taking mean effecting on account is given by

$$\boxed{W = P_m \times V_s}$$

Question For the diagram shown, show that the Mep is given by $P_m = \frac{\eta_v}{(\gamma-1)(r-1)} \times \Delta P$; where $\Delta P = P_3 - P_2$



show

$$P_m = \frac{\eta_v}{(\gamma-1)(r-1)} \times \Delta P$$

Sol^n

$$W = P_m \times V_s$$

$$\eta_v = \frac{WD}{HA}$$

or $$\eta_v = \frac{P_m \times V_s}{m C_v (T_3 - T_2)}$$

$$\eta_v = \frac{P_m \times V_s}{C_v \left[\frac{P_3V_3 - P_2V_2}{C_p - C_v} \right]}$$

$\because PV = mRT$

$R = C_p - C_v$

$$\eta_v = \frac{P_m \times V_s}{(P_3 - P_2) V_c} \frac{(C_p - C_v)}{C_v}$$

$\because V_c = V_2 = V_3$

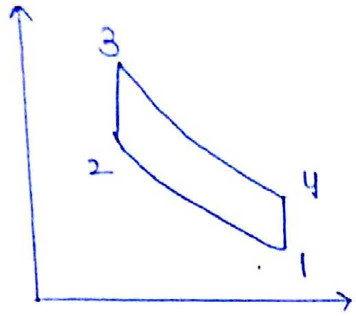
$$\eta_v = \frac{P_m \times (r-1)(\gamma-1)}{\Delta P}$$

$\therefore \frac{C_p - C_v}{C_v} = \frac{C_p}{C_v} - 1$

$= \gamma - 1$

$$\therefore \quad P_m = \frac{\eta_v}{(r-1)(\gamma-1)} \times \Delta P$$

Question:- For the diagram shown, show that $T_2 = T_4 = \sqrt{T_1 T_3}$ when work done is maximum.



show $T_2 = T_4 = \sqrt{T_1 T_3}$

Sol^n

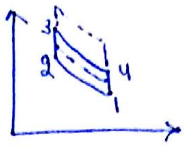
$$WD = HA - HR$$

$$WD = [m C_v (T_3 - T_2) - \{-mC_v (T_1 - T_4)\}]$$

$$W = mC_v(T_3 - T_2) - m C_v (T_4 - T_1)$$

$$\eta_v = \frac{WD}{HA}$$

if HA ↑ more than WD ↑
if HA ↓ ~~more~~ less than WD ↓



+ Compression Ratio is same For both exp. & Comp so we can convert it in single variable

* we can't solve this problem for Diesel Cycle because comp. ratio not equal.

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

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} = r^{-\gamma+1}$$

So
$$WD = mC_v\left[(T_3 - T_1 r^{\gamma-1}) - (T_3 r^{-\gamma+1} - T_1)\right]$$

For max WD, $\frac{d(WD)}{d(r)} = 0$

or $-T_1(\gamma-1) r^{(\gamma-1)-1} - T_3(-\gamma+1) r^{(-\gamma+1)-1} = 0$

$-T_1(\gamma-1) r^{\gamma-2} = -T_3(\gamma-1) r^{-\gamma}$

$r^{(\gamma-1)2} = \frac{T_3}{T_1}$ — (9)

$\left\{\frac{T_2}{T_1} = \frac{T_3}{T_4}\right\}$ or $\left(\frac{T_2}{T_1}\right)^2 = \frac{T_3}{T_1} \Rightarrow \therefore T_2 = \sqrt{T_1 T_3}$

& $\left(\frac{T_3}{T_4}\right)^2 = \frac{T_3}{T_1} \Rightarrow \therefore T_4 = \sqrt{T_1 T_3}$

$$\boxed{T_2 = T_4 = \sqrt{T_1 T_3}}$$

Question

When the work done of diesel cycle increase it efficiency will (a) increase (b) Remain Same ✓(c) Decrease (d) Anything is possible

Sol^n whenever question asked about efficiency start from eff. eq^n

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

HA, WD से ज्यादा बढ़ेगा

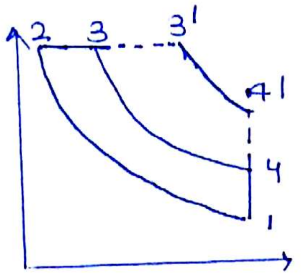
or $\frac{WD}{HA} = \eta_D = \frac{\{r^{\gamma-1} \times \gamma(\rho-1) - (\rho^\gamma - 1)\}}{\{r^{\gamma-1} \times \gamma(\rho-1)\}}$

Since the work done (Numenator) is increase, than heat added will increase even more as there is no −ve term in ~~demmomenater~~ (denominator). Hence efficiency will decrease.

Question The compression ratio of a diesel cycle is 16. Determine the % change in efficiency of cycle when the cutoff change to 5% to 15% of stroke.

Sol^n^

$r = 16$



$$r = 16 \Rightarrow \frac{V_1}{V_2} = 16$$

~~cutof $(V_3 - V_2) =$~~ $\quad V_2 = V_c$

$$\frac{V_c + V_s}{V_c} = 16$$

$$V_s = 15 V_c$$

when the cutoff takes place 5% of stroke

$$\frac{5}{100} V_s = V_3 - V_2$$

$$V_3 = 0.05(15 V_c) + V_c$$

$$V_3 = 1.75 V_c$$

$$\rho_1 = \frac{V_3}{V_2} = \frac{1.75 V_c}{V_c} = 1.75$$

when the cutoff takes place @ 15% of stroke

$$V_3' - V_2 = 0.15 V_s = 0.15(15 V_c)$$

$$V_3' = 3.25 V_c \qquad \rho_2 = \frac{V_3'}{V_2} = \frac{3.25 V_c}{V_c} = 3.25$$

$$\eta_1 = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \frac{\rho^{\gamma}-1}{\gamma(\rho-1)}$$

$$\eta_1 = 1 - \left(\frac{1}{16}\right)^{1.4-1} \frac{(1.75)^{1.4}-1}{1.4(1.75-1)} = 0.626$$

$$\eta_2 = 1 - \left(\frac{1}{16}\right)^{1.4-1} \frac{(3.25)^{1.4}-1}{1.4(3.25-1)} = 0.559$$

$$\%\text{ change in } \eta = \frac{0.626-0.559}{0.626} \times 100$$

$$\%\text{ change } \eta = 10.7\,\%$$

<u>Question</u> The Compression ~~of~~ ratio of an otto Cycle is 7. The intial Value of the Ratio of specific heat is 1.4 Find % change in the efficiency of cycle when the specific heat ~~and~~ at constant Volume is is increased by 1%.

<u>Soln</u>

$r = 7$

$$\gamma_1 = \frac{C_{p_1}}{C_{v_1}} = 1.4$$

$$\therefore C_{p_1} = 1.4\, C_{v_1}$$

% Change in η when

$C_{v_2} = 1.01\, C_{v_1}$

$$\text{so } \gamma_2 = \frac{C_{p_2}}{C_{v_2}} = \frac{C_{p_1}}{1.01 C_{v_1}} = \frac{1.4}{1.01}$$

$\gamma_2 =$

Since gas constant R Remain constant

$$C_{p_1} - C_{v_1} = R = C_{p_2} - C_{v_2}$$

$$C_{p_2} = (1.4 C_{v_1} - C_{v_1}) + 1.01 C_{v_1} \Rightarrow C_{p_2} = 1.41 C_{v_1}$$

$$\gamma_2 = \frac{C_{p_2}}{C_{v_1}} = \frac{1.41 C_{v_1}}{1.01 C_{v_1}} = 1.39$$

$$\eta_1 = 1 - \left(\frac{1}{r}\right)^{\gamma - 1} = 1 - \left(\frac{1}{7}\right)^{1.4 - 1} = 0.5407$$

$$\eta_2 = 1 - \left(\frac{1}{7}\right)^{1.39 - 1} = 0.531$$

$$\%\text{ change in } \eta = \frac{\eta_1 - \eta_2}{\eta_1} \times 100 = \frac{0.5407 - 0.537}{0.537} \times 100$$

$$\%\text{ change in } \eta =$$

Imp

* For any cycle if specific heat increase, γ decrease so efficiency also decrease

  * if $C_p, C_v \uparrow, \gamma \downarrow, \eta \downarrow$

  * if $C_p, C_v \downarrow, \gamma \uparrow, \eta \uparrow$

* For any cycle if comp. ratio (r) increase, efficiency of cycle will also increase.

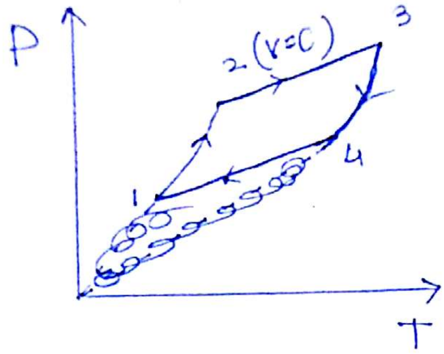
Workbook

Q.1 $(P)^{\frac{\gamma-1}{\gamma}} \propto T$ curved line

HA & HR $V = C$

$P \propto T$

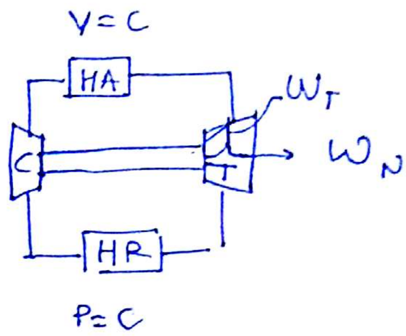
$P = C \times T \Rightarrow y = mx$



chose (B) correct

Q.2 (1) $\eta = \frac{WD}{HA}$ ✓

(2) Work Ratio $= \frac{W_{Net}}{W_{Turbine}}$ ✓



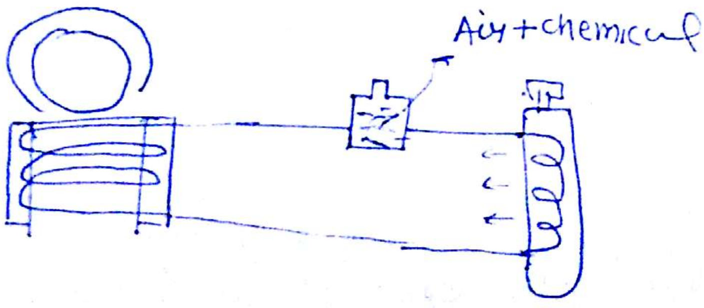
(3) $\frac{P_m}{P_{max}} = \frac{WD}{V_s \times P_{max}}$ ✓

(4) $\frac{Size}{Power} \Rightarrow \frac{Power}{Size}$ = Specific output ✓

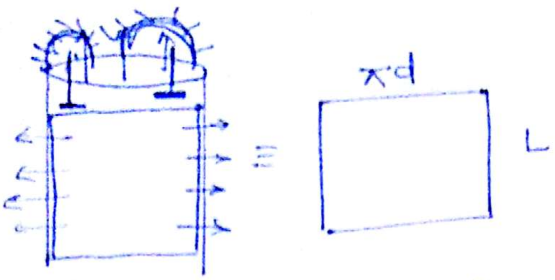
Power $\Rightarrow \frac{WD}{time \times size}$ ✓ it can be mass or volume.

D Ans

Cooling System



Q.3



$= \pi \times 2 \times 2 = 4\pi$ (best)

ऊपर व नीचे वाले part के Area को Heat loss के लिए consider नहीं करते | बहुत कम होता है (100 times)

if we Consider All surface $= 6\pi$

if we consider above surface $= 4\pi + \pi = 5\pi$

Q.4

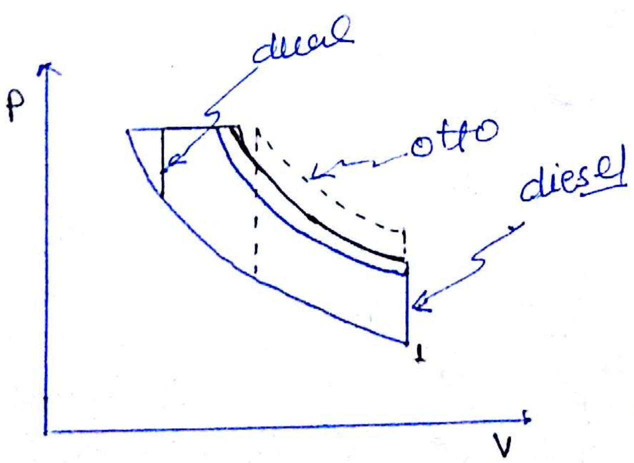
max. pressure and work output same

$$\eta = \frac{WD}{HA} = \frac{WD}{HR + WD}$$

it is clear from the above equation that if the heat rejection is more the efficiency of cycle will be less.

The 3 cycle are shown in P-V diagram below

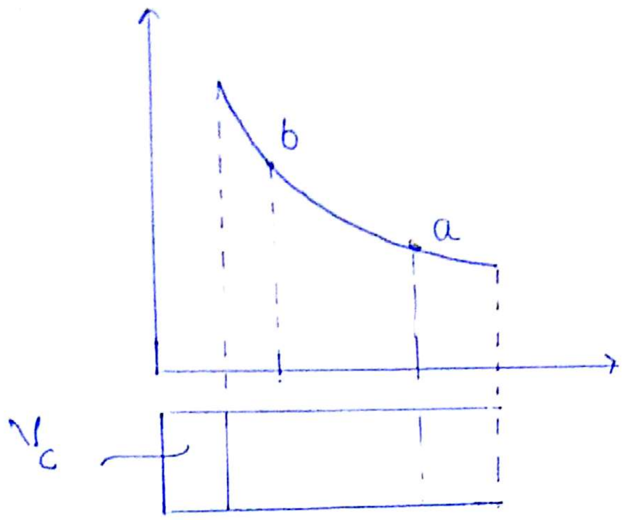
(Hint- Start with diesel cycle diagram)



$\eta_{diesel} > \eta_{dual} > \eta_{otto}$

It is should be notice that for same workdone (Area in P-V dia) is the same for all the cycle (Given). Hence, if the area for one cycle on left side, then the area for other cycle should be more on the right side it may be seen from dia that the HR is max for otto cycle and min for diesel cycle. ~~we have~~ so

Q.5



$P_a = 1.5$ bar

$V_a = \frac{7}{8} V_s + V_c$

$P_b = 15$ bar

$V_b = \frac{V_s}{8} + V_c$

$$P_a V_a^{1.4} = P_b V_b^{1.4}$$

$$1.5\left(V_c + \frac{7}{8} V_s\right)^{1.4} = 15\left(V_c + \frac{V_s}{8}\right)^{1.4}$$

$$V_s = 18.4 V_c$$

$$\frac{V_s}{V_c} = 18.4 = r - 1 \Rightarrow r = 19.4$$

Q.6 $r_1 = 16$ $r_2 = 20$ (25% increase)

$\gamma = 1.4$

$\rho = 4$

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

$$(\eta_p)_1 = 1 - \left(\frac{1}{16}\right)^{1.4-1} \frac{(4^{1.4} - 1)}{1.4(4-1)} \quad ; \quad (\eta_p)_2 = 1 - \left(\frac{1}{20}\right)^{1.4-1} \frac{(4^{1.4} - 1)}{1.4(4-1)}$$

$$(\eta_p)_1 = 0.5315 \qquad (\eta_p)_2 = 0.5715$$

$$\%\ \text{Change} = \frac{0.5715 - 0.5315}{0.5315} \times 100 = 7.5\%$$

increase

Q8 (a) All engine have hydrocarbon.

1kg petrol release more heat than 1kg diese

Q.12 r is same, HR is same

$$\eta = \frac{WD}{HA}$$

$$\eta = \frac{WD}{HR + WD}$$ So efficiency ~~tor~~ only depant WD.

$$\eta = \frac{1}{\frac{HR}{WD} + 1}$$

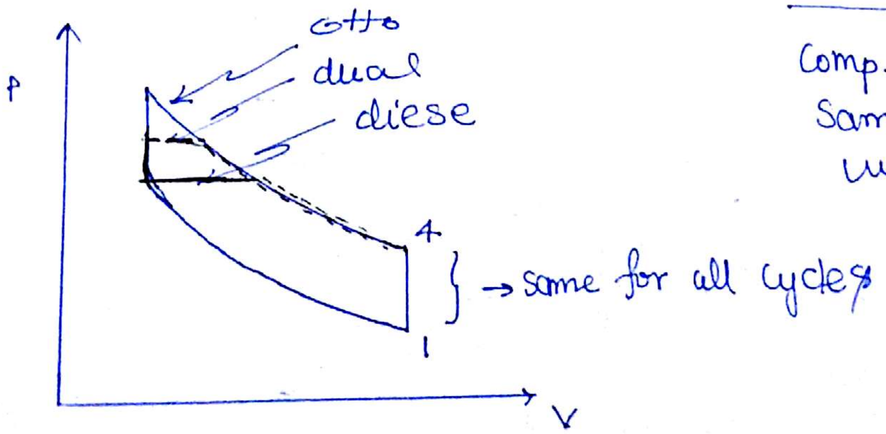
WD ↑, η ↑

WD ↓, η ↓

it clear from above ~~equal~~ equation that if WD is more, than the efficiency of cycle higher.

The three cycle are shown in diagram below.

Hint :- if Comp. ratio Same Start with otto Cycle.

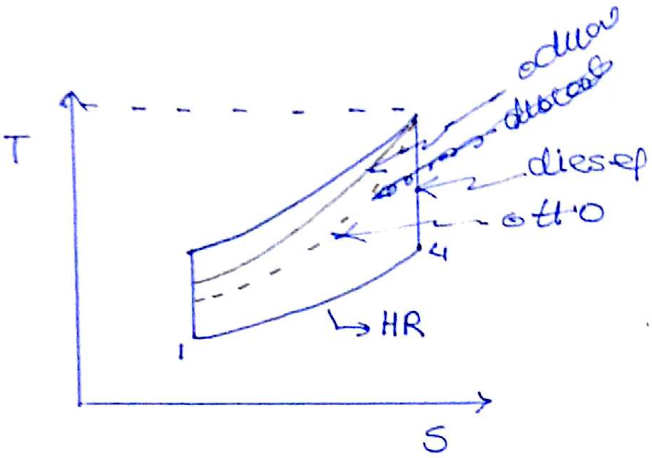


since the heat rejection is the same for all the cycle the initial condition of HR will also be same which is the same as the end of expansion this possible if the adiabatic expansion is shown along same for all the cycle. It may be seen from the diagram the area (word done) max. for otto cycle & mini for dieselcycle we thus have eff. of otto cycle max & effi of dieses cycle mini

$$\eta_{otto} > \eta_{dual} > \eta_{dieses}$$

(14) when WD ↑, load will ↑, thus we know that when load or WD ↑, $\eta \downarrow$ The reason is that to ↑ load cuttoff ratio ↑ & due to which HA will ↑ even more so $\eta \downarrow$

(15)



$$\eta = \frac{WD}{HA} = \frac{WD}{HR + WD}$$

$$\eta = \frac{1}{\frac{HR}{WD} + 1}$$

WD ↑, $\eta \uparrow$

WD ↓, $\eta \downarrow$

Cyclic dQ = Cyclic dW

The three cycle are shown in T-S diagram. From the equation for η, it can be understood that $\eta \uparrow$, WD will be more.

we know that Cyclic dQ = Cyclic dW $\left(= \frac{\text{Area of cycle}}{\text{T-S diagram}}\right)$

it may be seen from diagram that the area for diesel cycle is max. and min for otto cycle. we thus have

$$\eta_{diesel} > \eta_{dual} > \eta_{otto}$$

(18)

$d = 6.8\,mm$

$L = 2r_c$

$L = 2 \times 3.75\,cm$

$L = 7.5\,cm$

Find V_s/cycle

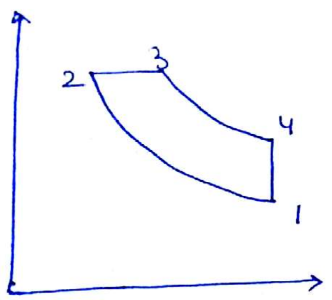
$V_s = \frac{\pi}{4} d^2 L$

$r = 8$

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

$$V_c = \frac{V_s}{8-1} \Rightarrow V_c = \frac{V_s}{8}$$

(19)



$$\frac{V_1}{V_2} = 15$$

$T_1 = 17^\circ C = 290\,K$

$T_4 = 417^\circ C = 690\,K$

$C_v = 0.717\ kJ/kg\text{-}K$

$r = 1.4$

$C_p =$

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

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

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{1.4-1}$$

$$T_2 = 990(15)^{0.4}$$

$$T_2 = 50.22^\circ C$$

$$P_1 V_1^r = P_2 V_2^r$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^r = P_1 \times 15^{1.4} = P_3$$

$\cancel{\frac{T_3}{T_2} = \frac{V_3}{V_2}}$ $\quad T_4 = T_1 \rho^r$

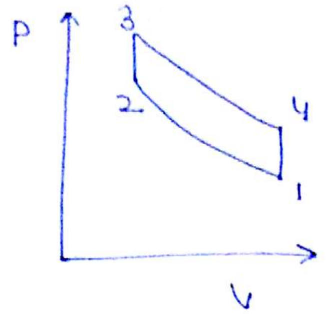
$$P_4 V_4^r = P_3 V_3^r$$

$$\therefore P_4 = P_3 \left(\frac{V_3}{V_4}\right)^r = P_3 \left(\frac{V_3}{V_2} \times \frac{V_2}{V_1}\right)^{1.4} = \left(\frac{\rho}{r}\right)^{1.4} \times P_1 \times 15^{1.4} \quad \text{— (a)}$$

$$\& \ \frac{P_4}{P_1} = \frac{T_4}{T_1} = \frac{690}{290} \Rightarrow P_4 = P_1 \times \frac{69}{29} \quad \text{— (b)}$$

$$\Rightarrow \left(\frac{\rho}{r}\right)^{1.4} \times \cancel{P_1} \times 15^{1.4} = \cancel{P_1} \times \frac{69}{29} \qquad \rho = ? \quad \cancel{97.86} \quad 1.8573$$

II



~~$r = 15$~~

$T_3 = 1400^\circ C = 1673\ K$

$T_1 = 15^\circ C = 288\ K$

$\frac{HA}{kg\ air} = 800\ kJ$

$r = ?\quad \eta_v = ?$

$P_3/P_1 = ?$

$$C_v(T_3 - T_2) = 800\ kJ$$

$C_v = 0.72\ kJ/kg\text{-}K$ (standard take it when not given

$\gamma = 1.4$

$$T_2 = 1673 - \frac{800}{0.72} = 557.2\ K$$

$$r = \frac{V_1}{V_2} = \left(\frac{T_2}{T_1}\right)^{1/\gamma-1} = \left(\frac{557.2}{288}\right)^{\frac{1}{1.4-1}} = \underline{5.07}$$

$$\eta_v = 1 - \left(\frac{1}{5.07}\right)^{1.4-1} = \underline{0.483}$$

$$\frac{P_3}{P_1} = \frac{P_3}{P_2} \times \frac{P_2}{P_1} = \frac{T_3}{T_2} \times \left(\frac{V_1}{V_2}\right)^{\gamma}$$

$$P_3/P_1 = \frac{1673}{557.2} \times 15^{1.4} = \underline{30.2}$$