Module 2- Thermal Engineering

Nov 20, APR 17

1 (b) A petrol engine (Otto cycle) works at a maximum temperature of 2000^0C and the temperature at the end of expansion is 800^0C. Find the following (Take γ =1.4) (i)the ideal thermal efficiency (ii) compression ratio (7)

2 (b) In an ideal Diesel cycle, the compression ratio is 15:1 and the expansion ratio is 7:5:1. The temperature and pressure at the beginning of compression are 44^0C and $98 kN/m^2$, respectively. Pressure at the end of Expansion is 258 kN/m^2. Determine the following (Take γ =1.4)

(i) the maximum temperature attained during the cycle.

(ii) the thermal efficiency of the cycle. (7)

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3 (b) Calculate the air standard efficiency of an engine working on Otto Cycle if the pressure at the beginning and end of the compression are 1 bar and 7 bar respectively. Take r =1.41. (8)

4. (b) An engine working on Carnot cycle receives heat at 700^0C and rejects heat at 50^0 C. Find the air standard efficiency of the cycle. It is absorbs 4000 KJ of heat per minute from the hot body calculate the work done and power of the engine. (8)

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5. (b) An engine working on Otto cycle has a volume of 0.45 m^3, pressure 1 bar and temperature 30°C at the beginning of compression stroke. At the end of compression stroke, the pressure is 11 bar. 210 kJ of heat is added at constant volume. Determine :

(i) Temperatures and volume after compression

(ii) Efficiency

6. (b) A Carnot engine working between 400°C and 40°C produces 130 kJ of work. Determine :

   (i) The engine thermal efficiency

   (ii) The heat added

   (iii) The entropy changes during heat rejection process. 7

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7. (b) An ideal diesel engine has a bore diagram 150mm and stroke 200mm. The clearance volume is 10% of the swept volume. Determine the compression ratio and air standard efficiency of the engine, if the cut off take place at 6% of the stroke. 8

8 (b) 0.23kg of gas is taken through a Carnot cycle whose temperature limits are 300°C and 50°C. If the Volume ratio of expansion of the isothermals is 2.5, determine (i) air standard efficiency of cycle and (ii) work done per cycle. Take R = 0.28kJ/kgK. 8

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9. (b) A Carnot engine works with isentropic compression ratio of 5 and isothermal expansion Ratio of 2. The volume of air at the beginning of isothermal expansion is 0.3 m³ . If the Maximum temperature and pressure is limited to 550 K and 21 bar. Determine

   (i) Minimum temperature

   (ii) Air standard efficiency of the cycle

   (iii) Pressure at the end of isothermal expansion

   Take $\gamma = 1.4$ 7

10. (b) A certain quantity of air at a pressure 1 bar and temperature 70°C is compressed Isentropically to the pressure of 7 bar in an Otto cycle engine. Heat is now added at the rate of 460 KJ per Kg of air at constant volume. Determine, (i) compression ratio of the engine (ii) temperature at the end of compression and (iii) temperature at the end of heat addition. Assume Cp = 1 KJ/Kg K and Cv = 0.707 KJ/Kg K. 7

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11 V (a) The air standard efficiency of a Otto cycle engine is 51%. The pressure and temperature at the beginning of isentropic compression are 1.5 bar and 25° C respectively. Calculate,

(i) Compression ratio

(ii) Temperature at the end of compression

(iii) Pressure at the end of compression (assume $\gamma = 1.4$) 8

12 (b) In a diesel engine the compression ratio is 13 : 1 and the fuel is cut off at 8 % of the Stroke. Find the air standard efficiency of the engine. Take $\gamma = 1.4$ for air. 7

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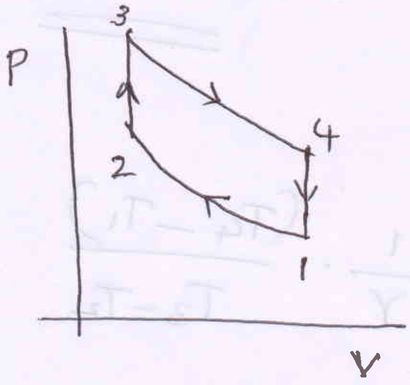
13 (b) A Carnot cycle works with isentropic compression ratio 5 and the maximum temperature is limited to 550K. Compute the minimum temperature in the cycle and air standard efficiency of the cycle.

Take ratio of specific heats as 1.4. 8

Module 2 - Thermal Engineering

NOV 20, APR 17

1. Given Data



$T_3 = 2000°C = 2273\ K$

$T_4 = 800°C = 1073\ K$

$\gamma = 1.4$

$$\eta_{otto} = 1 - \frac{T_4}{T_3} = 1 - \frac{1073}{2273} = 52.8\ \%$$

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

$$\text{ie } r = \left(\frac{2273}{1073}\right)^{1.4-1} = 6.53$$

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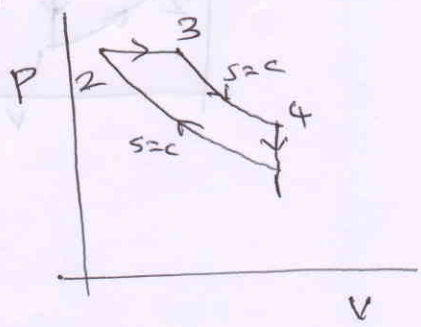
2. Given Data $P_1 = 98\ kN/m^2$ $T_1 = 44°C$

$P_4 = 258\ kN/m^2$ $\gamma = 1.4$

$r = 15$ $r_e = 7.5$

Find T_3, η_{diesel}.



For process 4-1

$$\frac{P_4}{T_4} = \frac{P_1}{T_1} \Rightarrow T_4 = T_1 \times \frac{P_4}{P_1}$$

$$= 317 \times \frac{258}{98} = 834.6\ K$$

For process 3 - 4

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

$$= 834.6 \times 7.5^{0.4}$$

$$= 1868.5\ K$$

(i) Maximum temperature attained during the cycle $T_3 = 1868.5\,K$

$$= 1868.5 - 273 = 1595.5\,^{\circ}C$$

(ii) Thermal efficiency

$$\eta_{diesel} = 1 - \frac{1}{\gamma} \cdot \frac{(T_4 - T_1)}{T_3 - T_2}$$

$$T_2 = T_1 \cdot r^{\gamma - 1} = 317 \times 15^{1.4-1} = 936.5\,K$$

$$\therefore \eta_{diesel} = 1 - \frac{1}{1.4} \times \frac{(834.6 - 317)}{(1868.5 - 936.5)}$$

$$= 60.33\,\%$$

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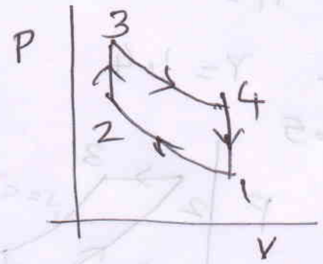
3. Given Data $P_1 = 1$ bar $P_2 = 7$ bar $\gamma = 1.41$



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

$$\therefore \text{Compression ratio } r = \left(\frac{P_2}{P_1}\right)^{1/\gamma}$$

$$r = \left(\frac{7}{1}\right)^{1/1.41} = 3.98$$

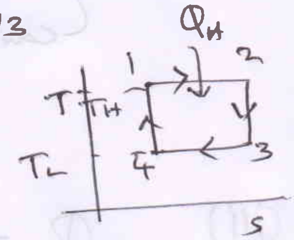
$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{3.98^{1.4-1}} = 42.45\,\%$$

APR 20

4. Given Data $T_H = 700°c$ $T_L = 50°c$

$$Q_H = 4000 \text{ kJ/min}$$

$$\eta_{carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{50+273}{700+273} = 66.8\%.$$



$$\eta_{carnot} = \frac{W}{Q_H}$$

Workdone, ∴ $W = \eta_{carnot} \times Q_H = 0.668 \times 4000$

$$= 2672 \text{ kJ/~~of heat from~~ min}.$$

Power of the engine $= 2672$ kJ/min

$$= \frac{2672}{60} \text{ kJ/s}$$

$$= \underline{\underline{44.53 \text{ kW}}}$$

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5. Given Data $V_1 = 0.45 \, m^3$ $P_1 = 1$ bar $T_1 = 30°c$

$Q_H = 210$ kJ

$P_2 = 11$ bar

Compression ratio $r = \left(\frac{P_2}{P_1}\right)^{1/\gamma} = \left(\frac{11}{1}\right)^{1/1.4} = 5.54$

(i) $T_2 = T_1 \cdot r^{\gamma-1} = 303 \times (5.54)^{1.4-1} = 600.96$ K

$$V_2 = \frac{V_1}{r} = \frac{0.45}{5.54} = 0.081 \, m^3$$

(ii) $\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{5.54^{1.4-1}} = 49.58\%$

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6. Given Data $T_H = 400°c$ $T_L = 40°c$ $W = 130\ kJ$

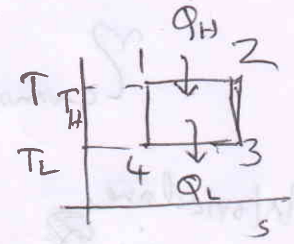
(i)

$$\eta_{carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{40+273}{400+273} = 53.5\ \%$$

(ii)

$$\eta_{carnot} = \frac{W}{Q_H} \Rightarrow Q_H = \frac{W}{\eta_{carnot}} = \frac{130}{0.535} = 243\ kJ$$

(iii)



$$Q_L = Q_H - W \quad \cancel{243} -$$

$$= 243 - 130 = 113\ kJ$$

$$S_3 - S_4 = \frac{Q_L}{T_L} = \frac{113}{313} = 0.361\ kJ/K$$

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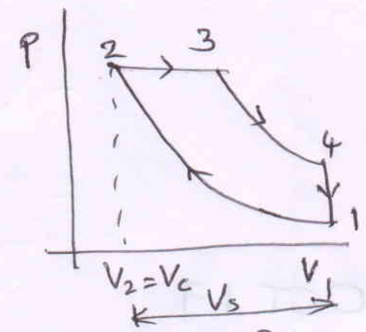
7. Given Data $D = 150\ mm = 0.15\ m$

$L = 200\ mm = 0.2\ m$



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$V_c = 10\%\ V_s$

$$\frac{V_3 - V_c}{V_s} = 6\%$$

$$V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times 0.15^2 \times 0.2 = \underline{0.0035}\ m^3$$

$$V_c = 0.1 \times V_s = 0.1 \times 0.0035 = 0.00035\ m^3$$

Total cylinder Volume $V_1 = V_c + V_s = 0.00035 + 0.0035$

$$= 0.00385\ m^3$$

Compression ratio $r = \frac{V_1}{V_c} = \frac{0.00385}{0.00035} = 11$

Cut off ratio $\rho = 1 + 0.06[r - 1]$

$= 1 + 0.06[11 - 1] = 1.6$

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

$$= 1 - \frac{1}{11^{1.4-1}} \times \left[\frac{1.6^{1.4} - 1}{1.4(1.6-1)}\right] = 57.53\ \%$$

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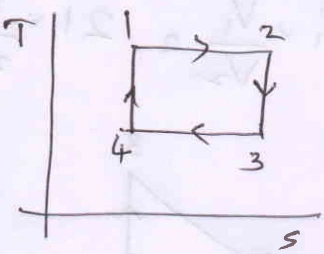
8. Given Data $m = 0.23$ kg $T_H = 300°C$ $T_L = 50°C$



$r = \frac{V_2}{V_1} = 2.5$ $R = 0.28$ kJ/kg.K

$$\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{50+273}{300+273} = 43.63\ \%$$

Workdone/cycle $= Q_H - Q_L$

$= mRT_H \ln r - mRT_L \ln r$

$= mR(T_H - T_L) \cdot \ln r$

$= 0.23 \times 0.28 \times (573 - 323) \cdot \ln 2.5$

$= \underline{\underline{14.75 \text{ kJ}}}$

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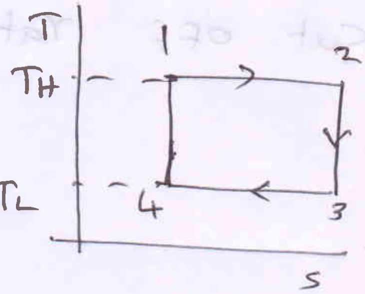
9.

Given Data



$\frac{V_4}{V_1} = 5$ $\quad \frac{V_2}{V_1} = 2$ $\quad V_1 = 0.3 m^3$

$T_H = T_1 = T_2 = 550$ K $\quad P_1 = 21$ bar

$$\frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \Rightarrow T_4 = \frac{T_1}{(V_4/V_1)^{\gamma-1}} = \frac{550}{5^{1.4-1}} = 288.92 \text{ K}$$

(i) ie $T_4 = \underline{\underline{15.92}}$ °K $= T_L$

(ii) $\eta_{carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{288.92}{550} = 47.47\%$

(iii) $P_1 V_1 = P_2 V_2 \Rightarrow P_2 = P_1 \times \frac{V_1}{V_2} = 21 \times \frac{1}{2} = \underline{\underline{10.5 \text{ bar}}}$

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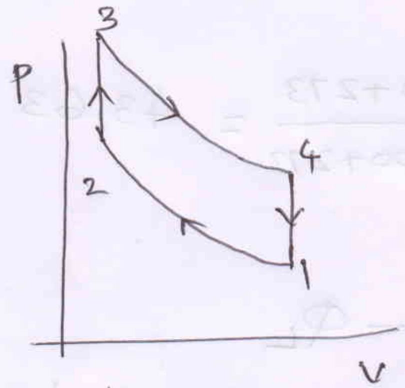

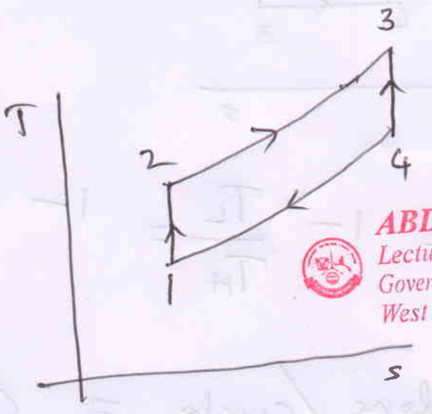

Given Data

$P_1 = 1$ bar $\quad T_1 = 70°C \quad P_2 = 7$ bar

$Q_H = 460$ kJ/kg $\quad C_p = 1$ kJ/kg.k $\quad C_v = 0.707$ kJ/kg.k

Ratio of specific heat $\gamma = \frac{C_p}{C_v} = \frac{1}{0.707} = 1.41$

(i) Compression ratio $r = \left(\frac{P_2}{P_1}\right)^{1/\gamma} = \left(\frac{7}{1}\right)^{1/1.41} = 3.98$

(ii)

$$T_2 = T_1 \cdot \gamma^{\gamma-1} = 343 \times 3.98^{1.4-1} = \cancel{596\ K}$$

$$= 604.29\ K$$

(iii)

$$Q_H = C_v (T_3 - T_2)$$

$$460 = 0.707 (T_3 - 604.29)$$

ie $T_3 = 1254.93\ K$

$$= 981.93\ ^\circ C$$

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11 Given Data $\eta_{otto} = 51\%$ $P_1 = 1.5$ bar $T_1 = 25^\circ C$ $\gamma = 1.4$

(i)

$$\eta_{otto} = 1 - \frac{1}{\gamma^{\gamma-1}} \Rightarrow 0.51 = 1 - \frac{1}{\gamma^{1.4-1}}$$

$$\Rightarrow \gamma = 5.95$$

(ii) $$T_2 = T_1 \times \gamma^{\gamma-1} = 298 \times 5.95^{1.4-1} = 608.17\ K$$

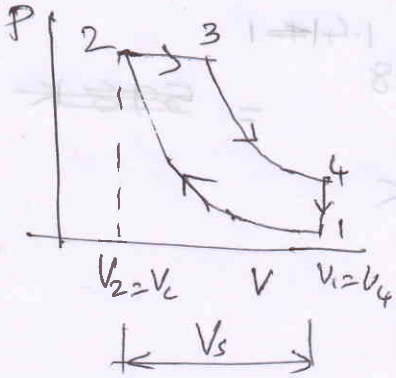
ie $T_2 = 335.17\ ^\circ C$

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

$$= P_1 \times \gamma^\gamma = 1.5 \times 5.95^{1.4}$$

$$= \underline{18.21\ \text{bar}}$$

12. Given Data $\gamma = 13$ $\frac{V_3 - V_c}{V_s} = 8\%$ $\gamma = 1.4$



$$\rho = 1 + 0.08 (\gamma - 1)$$

$$= 1 + 0.08 (13 - 1)$$

$$= 1.96$$

$$\eta_{diesel} = 1 - \frac{1}{\gamma^{\gamma-1}} \left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)} \right]$$

$$= 1 - \frac{1}{13^{1.4-1}} \left[\frac{1.96^{1.4} - 1}{1.4 (1.96 - 1)} \right]$$

$$= \underline{\underline{58.25 \%}}$$

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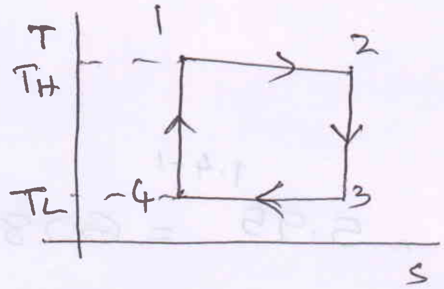
13.



Given $\frac{V_4}{V_1} = 5$

$T_H = T_1 = T_2 = 550$ K

$\gamma = 1.4$

$$\frac{T_H}{T_L} = \frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \Rightarrow T_L = \frac{T_H}{(V_4/V_1)^{\gamma-1}} = \frac{550}{5^{1.4-1}}$$

ie $T_L = \underline{\underline{288.92}}$ K

$$\eta_{carnot} = 1 - \frac{T_L}{T_H} = 1 - \frac{288.92}{550}$$

$$= \underline{\underline{47.47 \%}}$$