Module 3- Thermal Engineering

Nov 20

1 (b) Steam approaches a nozzle with a velocity 250m/s, pressure of 3.5 bar and dryness fraction 0.95. If the isentropic expansion in the nozzle proceeds till the pressure of the exit is 2 bar. Determine the change in enthalpy and the dryness fraction of steam using mollier chart. Calculate also the exit velocity from the nozzle. (7)

2 (b) A four cylinder four stroke engine develops 30kW BP at 5000 rpm. The mean effective pressure on each piston is 900kPa and the mechanical efficiency is 85%. Calculate the diameter and stroke length of each cylinder, assuming the length of stroke is 1.5 times the diameter of cylinder. (7)

APR 20

3 (b) A 4 cylinder, 4 stroke petrol engine runs at 1200 rpm. Bore diameter of cylinder is 0.09m and stroke is 0.120m. The mean effective pressure in each cylinder is 500 Kpa. Mechanical efficiency being 75%. Calculate indicate power and brake power of the engine. (8)

4. (b) Using Mollier diagram, determine the specific enthalpy and specific entropy of wet steam of quality 0.85 at 2 bar pressure. (8)

OCT 19

5 (b) A single cylinder, 4 stroke cycle engine was tested and following results were obtained.

Mean height of indicator diagram	—	21mm
Indicator spring number	—	27 $kN/m^2/mm$
Swept volume of cylinder	—	14 litres
Speed of engine	—	396 rpm
Brake load	—	77 kg.
Brake drum radius	—	700 mm

Determine : (i) Indicated power (ii) Brake power (iii) Mechanical efficiency 7

6. (b) 4 Kg of 0.5 dryness fraction steam at 6 bar pressure is heated so that it becomes :

Case I : 0.95 dry at 6 bar pressure.

Case II : Dry and saturated at 6 bar pressure

Determine in each case the quantity of heat required to be supplied. 7

APR 19

7 (b) A two cylinder 4-stroke cycle I C engine is to be designed to develop 15kW IP at 1200 RPM. The m.e.p of the cycle is limited to 6 bar. Determine the bore diameter and stroke of the engine if stroke = 1.2 × bore diameter. 8

8 (b) Calculate the total heat of 5kg of steam at an absolute pressure of 8 bar having dryness fraction of 0.8. Also calculate heat required in kJ to convert the steam in to dry and saturated steam. 8

OCT 18

9. (a) The following observations are made during a trial of a jacketed simple steam engine.

Pressure of steam supplied	= 10 bar
Cylinder feed	= 13.5 kg/min
Jacket feed	= 1.5 kg/min
Condition of cylinder and jacket feed	= 95% dry
Mass of circulating water	= 220 kg/min
Outlet temperature	= 35° C
Inlet temperature	= 15° C
Condenser temperature	= 50° C
Temperature of jacket drain	= 150° C
Indicated power	= 80 KW

Prepare a Heat Balance Sheet for the engine. 8

APR 18

10 (b) Dry saturated steam at a pressure of 10 bar is expanded in a nozzle to a pressure of 0.7 bar. Using Mollier diagram find the velocity and dryness fraction of steam issuing from the nozzle under following conditions.

(i) Friction in the nozzle is neglected.

(ii) 15 % of the heat drop is lost in friction. 7

11 (a) Determine the quantity of heat required to produce 1 kg of steam at a pressure of 6 bar and a temperature of 25°C, under following conditions.

(i) When steam is wet and having a dryness fraction 0.9

(ii) When the steam is dry saturated, and

(iii) When it is superheated at a constant pressure at 250°C assuming the mean Specific heat of superheated steam to be 2.3 KJ/Kg K. 8

OCT 17

12 A petrol engine develops 7.5 kw IP. Fuel consumption is 2 kg/hr and calorific value of fuel is 42000 kj/kg. If it's compression ratio is 6, calculate relative efficiency of the engine.

13 (a) A rope brake dynamometer fitted on an engine has wheel diameter 600mm and rope diameter 5mm. The dead load on the wheel is 210N and spring balance reads 30N. If the engine makes 450 rpm, find the brake power developed by the engine. 7

14. I (a) Determine the quantity of heat required to produce 1kg of wet steam with dryness fraction 0.9 at a pressure of 6 bar from water at 25° C.

APR 17

15 (b) An IC engine develops a B.P. of 10 kW. Its friction power is 2.3kW. Determine the mechanical efficiency at 0, 5 and 10kW output. If the thermal efficiency is 22%, determine S.F.C/kWh for a fuel of 38000 kJ/kg. 8

16 (b) A four cylinder 4 stroke petrol engine runs at 1200 RPM. Bore diameter of cylinder is 90mm and stroke 120mm. The mean effective pressure in each cylinder is 5 bar. Mechanical efficiency being 75%. Calculate IP and BP of the engine. 8

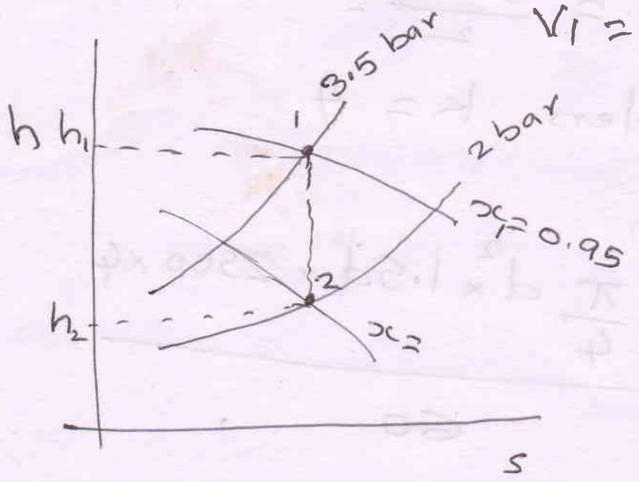
Module 3 - Thermal Engineering

NOV 20

1. Given Data $P_1 = 3.5$ bar $x_1 = 0.95$

$P_2 = 2$ bar $\Delta h = ?$ $x_2 = ?$

$V_1 = 250$ m/s



From mollier diagram

$h_1 = 2624$ kJ/kg.

$h_2 = 2534$ kJ/kg.

$x_2 = 0.92$

Change in enthalpy $\Delta h = h_1 - h_2$

$= 2624 - 2534$

$= 90$ kJ/kg.

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$$V_{exit} = \sqrt{V_1^2 + 2000\,(h_1 - h_2)}$$

$$= \sqrt{250^2 + 2000\,(2624 - 2534)}$$

$$= 492.4 \text{ m/s.}$$

NOV 20

2. Given Data $BP = 30$ kW $N = 5000$ rpm

$P_m = 9000$ kPa $\eta_m = 85\%$

$L = 1.5\,d$ $d = ?$ $L = ?$

$$IP = \frac{BP}{\eta_m} = \frac{30}{0.85} = 35.294 \text{ kW}$$

$$IP = \frac{P_m \cdot ALnk}{60}.$$

number of power strokes/min for a Foure Stroke engine $n = \frac{N}{2} = \frac{5000}{2} = 2500$

Number of cylinders $k = 4$

$$35.294 = \frac{900 \times \frac{\pi}{4} d^2 \times 1.5d \times 2500 \times 4}{60}$$

$$d^3 = 0.0002 \ m^3$$

$$\Rightarrow d = 0.0585 \ m = 58.5 \ mm$$

$$L = 1.5\,d = 1.5 \times 58.5 = \underline{\underline{87.75 \ mm}}$$

APR 20

3. Given Data $k = 4$ $N = 1200$ rpm

$L = 0.12$ m

$d = 0.09$ m

$P_m = 500$ kPa $\eta_m = 75\%$

$IP = ?$ $BP = ?$

Here For a Four stroke engine, Number of Power strokes per min $n = \frac{N}{2}$

ie $n = \frac{N}{2} = \frac{1200}{2} = 600$

$$Ip = \frac{P_m \cdot ALnk}{60} = \frac{500 \times \frac{\pi}{4} \times 0.09^2 \times 0.12 \times 600 \times 4}{60}$$

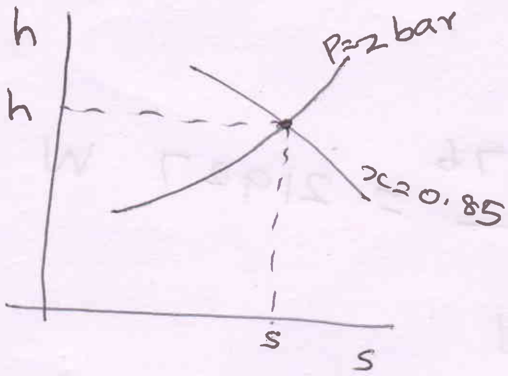
ie $IP = 15.27$ kW

$$BP = IP \times \eta_m$$

$$= 15.27 \times 0.75 = \underline{11.45 \text{ kW}}$$

APR 20

4



From mollier diagram.

$h = 2380$ kJ/kg

$s = 6.26$ kJ/kg.K

OCT 19

5 Given Data

Mean height of Indicator diagram = 21 mm

Indicator spring number = 27 kN/m² /mm

$V_s = 14$ litres $N = 396$ rpm $k=1$

Brake load = 77 kg Brake drum radius = 700 mm

P_m = Mean height of Indicator diagram × Spring number

$$= 21 \times 27 = 567 \text{ kN/m}^2$$

(i)

$$IP = \frac{P_m A L n k}{60} = \frac{567 \times (14 \times 10^{-3}) \times \frac{396}{2} \times 1}{60}$$

$$= \underline{26.2 \text{ kW}}$$

$$BP = \frac{2\pi N T}{60}$$

$T =$ Brake load x Brake drum radius

$= 77\ kg \times 9.81\ m/s^2 \times 700 \times 10^{-3}$

$= 528.76\ N\text{-}m$

(ii)

$$BP = \frac{2\pi \times 396 \times 528.76}{60} = 21927\ W$$

$= 21.927\ kW$

(iii)

$$\eta_m = \frac{BP}{IP} = \frac{21.927}{26.2} = 83.69\ \%$$

OCT 19

6 Given Data $m = 4\ kg$ $x_1 = 0.5$ $P = 6$ bar

Case 1 : $x_2 = 0.95$ $P_2 = 6$ bar

Case 2 : $x_2 = 1$ $P_2 = 6$ bar.

From steam table At 6 bar pressure

$h_{fg} = 2085.1\ kJ/kg$

$h_f = 670.4\ kJ/kg$

$\therefore$ Initial specific enthalpy of steam $(x = 0.5)$

$h_1 = h_f + x \cdot h_{fg} = 670.4 + 0.5 \times 2085.1$

$= 1712.95\ kJ/kg.$

Case 1

Final specific enthalpy

$$h_2 = h_f + x_i h_{fg}$$
$$= 670.4 + 0.95 \times 2085.1$$
$$= 2651.25 \text{ kJ/kg}.$$

$$\therefore \text{Heat added} = m(h_2 - h_1) = 4(2651.25 - 1712.95)$$
$$= \underline{\underline{3753.2 \text{ kJ}}}$$

Case 2

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Final specific Enthalpy

$$h_2 = h_f + x_2 h_{fg}.$$
$$= 670.4 + 1 \times 2085.1$$
$$= 2755.5$$

$$\text{Heat added} = m(h_2 - h_1)$$
$$= 4(\cancel{2651}\ 2755.5 - 1712.95)$$
$$= \underline{\underline{4170.2 \text{ kJ}}}$$

APR 19

7 Given Data IP = 15 kW k = 2 N = 1200 rpm

$P_m = 6$ bar $d = ?$ $L = ?$ $L = 1.2d.$

Number of Power strokes/min $n = \frac{N}{2} = \frac{1200}{2} = 600$

$$IP = \frac{P_m \cdot A L n k}{60} \Rightarrow \cancel{15 \text{ kW}}\ 15 = \frac{600 \times \frac{\pi}{4} d^2 \times 1.2d \times 600 \times 2}{60}$$

$d^3 = 0.001326$

$d = 0.1098\ m = 109.8\ mm$

$L = 1.2\,d = 1.2 \times 109.8 = 131.76\ mm$

APR 19

8 Given Data $m = 5\ kg$ $P = 8\ bar$ $x = 0.8$

Find ~~specific~~ enthalpy of wet steam

From steam table at 8 bar

$h_f = 720.9\ kJ/kg$ $h_{fg} = 2046.5\ kJ/kg$

$h_g = 2767.4\ kJ/kg.$

$\therefore$ specific enthalpy of wet steam

$h_1 = h_f + x \cdot h_{fg} = 720.9 + 0.8 \times 2046.5$

$= 2358.1\ kJ/kg.$

Total heat of 5 kg of steam

$H_1 = m \times h_1 = 5 \times 2358.1$

$= 11790.5\ kJ$

Total Heat of 5 kg of dry saturated steam

$H_2 = m \times h_g = 5 \times 2767.4$

$= 13837\ kJ$

$\therefore$ Net heat required to be supplied for conversion of wet steam to dry saturated steam

$= H_2 - H_1 = 13837 - 11790.5 = \underline{2046.5\ kJ}$

OCT 18

9 Given Data $P = 10$ bar $t_c = 50°C$

$m_s = 13.5$ kg/min $t_j = 150°C$

$m_j = 1.5$ kg/min $IP = 80$ kW

$x = 0.95$ $t_i = 15°C$

$m_c = 220$ kg/min

$t_o = 35°C$

From steam table at 10 bar

$h_f = 762.6$ kJ/kg $h_{fg} = 2013.6$ kJ/kg

Heat of steam supplied per kg

$h = h_f + x \cdot h_{fg} = 762.6 + 0.95 \times 2013.6$

$= 2675.5$ kJ/kg

Total heat supplied to the cylinder

$= h\,(m_s + m_j)$

$= 2675.5\,(13.5 + 1.5)$

$= 40132.5$ kJ/min

Heat absorbed in IP $= IP \times 60 = 80 \times 60$

$= 4800$ kJ/min

Heat rejected to the cooling water

$= m_{cw} C_w (t_o - t_i)$

$= 220 \times 4.2 \times (35 - 15) = 18480$ kJ/m

Heat rejected in Condensate

$= m_s C_w t_c$

$= 13.5 \times 4.2 \times 50$

$= 2835 \text{ kJ/min}$

Heat rejected in Jacket drain

$= m_j \cdot C_w \cdot t_j = 1.5 \times 4.2 \times 150$

$= 945 \text{ kJ/min}$

Unaccounted heat

$= 40132.5 - (4800 + 18480 + 2835 + 945)$

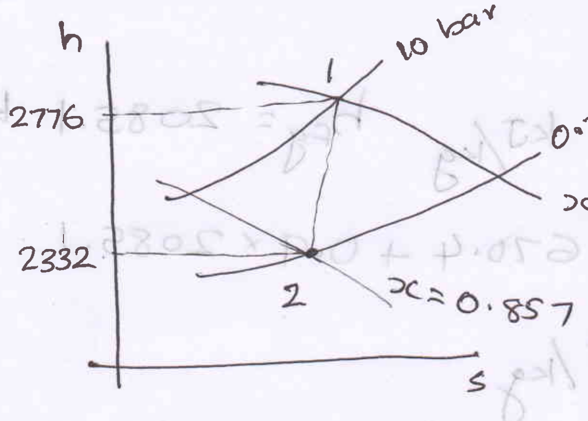
$= 13072 \text{ kJ/min}$

Heat balance sheet

Sl No.	Particulars	Heat in kJ/min	Heat in %
	Total Heat supplied	40132.5	100
1.	Heat absorbed in IP	4800	11.96
2.	Heat rejected in Cooling water	18480	46.05
3.	Heat rejected in Condensate	2835	7.06
4.	Heat rejected in Jacket drain	945	2.35
5.	Unaccounted Heat	13072	32.57

APR 18

10 Given Data $P_1 = 10$ bar $x = 1$ $P_2 = 0.7$ bar



From mollier diagram

$h_1 = 2776$ kJ/kg

$h_2 = 2332$ kJ/kg

$x_2 = 0.857$

ie Dryness fraction at exit of Nozzle $x_2 = 0.857$

Enthalpy drop $h_d = h_1 - h_2 = 2776 - 2332 = 444$ kJ/kg

Case (i) [Friction in Nozzle is neglected]

Velocity at exit of Nozzle $V_2 = \sqrt{2000\, h_d}$

$= \sqrt{2000 \times 444} = 942.3$ m/s.

Case (ii) [15% of the heat drop is lost in friction]

Here nozzle coefficient $k = 1 - 0.15 = 0.85$

$V_2 = \sqrt{2000\, k \cdot h_d} = \sqrt{2000 \times 0.85 \times 444} = 868.8$ m/s

APR 18

11. Given Data $m = 1$ kg $P_1 = 6$ bar $T = 25°C$

$C_{p\,steam} = 2.3$ kJ/kg.K

~~At 6 bar~~

Heat already in water $h_1 = C_w \times t$

$= 4.2 \times 25°C$

$= 105$ kJ/kg

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(i) When steam is wet and having dryness fraction 0.9

At 6 bar $h_f = 670.4$ kJ/kg $h_{fg} = 2085.1$ kJ/kg

$\therefore h_2 = h_f + x \cdot h_{fg} = 670.4 + 0.9 \times 2085.1$

$= 2546.99$ kJ/kg

$\therefore$ Heat required $= m(h_2 - h_1) = 1(2546.99 - 105)$

$= \underline{2441.99}$ kJ

(ii) When the steam is dry saturated.

At 6 bar $h_g = 2755.5$ kJ/kg

$h_2 = h_g = 2755.5$ kJ/kg

$\therefore$ Heat required $= m(h_2 - h_1) = 1(2755.5 - 105)$

$= \underline{\underline{2650.5}}$ kJ

(iii) When it is superheated at constant pressure at 250° C.

~~From steam table At 6 bar 250°C~~ ~~$h_2 = 2957.6$ kJ/kg.~~

At 6 bar $h_g = 2755.5$ kJ/kg

$\therefore$ ~~Heat r~~ $T_{sat} = 158.8$ °C.

$h_2 = h_g + C_p(T_{sup} - T_{sat}) = 2755.5 + 2.3(250 - 158.8)$

$= 2965.26$ kJ/kg.

Heat required $= m(h_2 - h_1) = 1(2965.26 - 105) = \underline{\underline{2860.26}}$ kJ

OCT 17

12 Given Data, Indicated thermal power $IP = 7.5\ kW$.

$\dot{m}_f = 2\ kg/h = 2/3600\ kg/s$.

$CV = 42000\ kJ/kg$.

$r = 6$.

Indicated Thermal efficiency $= \dfrac{IP}{\dot{m}_f \times CV}$

$= \dfrac{7.5}{(2/3600) \times 42000} = 32.14\ \%$.

Air standard efficiency, $\eta_{otto} = 1 - \dfrac{1}{r^{\gamma-1}}$

$= 1 - \dfrac{1}{6^{1.4-1}} = 51.164\%$

$\therefore$ Relative efficiency $= \dfrac{\text{Indicated thermal efficiency}}{\text{Air standared efficiency}}$

$= \dfrac{0.3214}{0.51164} = 62.82\ \%$

OCT 17

13 Given Data $N = 450\ rpm$ $W = 210N$

$S = 30\ N$ $D = 600\ mm = 0.6\ m$

$d = 5mm = 0.005\ m$

$BP = \dfrac{\pi (D+d) N (W-S)}{60} = \dfrac{\pi \times (0.6+0.005) \times 450 \times (210-30)}{60}$

$= 2565.9\ W \simeq \underline{2.57\ kW}$

OCT 17

14. Given Data, $m = 1$ kg $P_1 = 6$ bar $= P_2$

$T = 25°C$. $x_2 = 0.9$.

Heat already in water $h_1 = C_w \times t$

$= 4.2 \times 25 = 105$ kJ/kg

At 6 bar $h_f = 670.4$ kJ/kg $h_{fg} = 2085.1$ kJ/kg

$\therefore h_2 = h_f + x.h_{fg} = 670.4 + 0.9 \times 2085.1$

$= 2546.99$ kJ/kg.

$\therefore$ Heat required $= m(h_2 - h_1) = 1(2546.99 - 105)$

$= 2441.99$ kJ

APR 17

15 Given Data BP = 10 kW

FP = 2.3 kW

$\eta_b = 22\%$

CV = 38000 kJ/kg.

$$\eta_m = \frac{BP}{Ip} = \frac{BP}{BP + FP}$$

At 0 kW output BP = 0 $\therefore IP = BP + FP = 0 + 2.3$

$= 2.3$ kW.

$$\therefore \eta_m = \frac{BP}{Ip} = \frac{0}{2.3} = 0\%$$

At $BP = 5\,kW$

$$\eta_m = \frac{BP}{BP+FP} = \frac{5}{5+2.3} = \frac{5}{7.3} = 68.49\%$$

At $BP = 10\,kW$

$$\eta_m = \frac{BP}{BP+FP} = \frac{10}{10+2.3} = \frac{10}{12.3} = 81.3\%$$

$$SFC = \frac{3600}{\eta_b \times CV} = \frac{3600}{0.22 \times 38000} = 0.43\ kg/kWh$$

APR 17

16. Given Data $k = 4$ number of ~~stroke~~ $= 4$

$N = 1200$ rpm $d = 0.09$ m

$L = 0.12$ m $P_m = 500$ kPa

$\eta_m = 0.75$

$$n = \frac{N}{2} = \frac{1200}{2} = 600$$

$$IP = \frac{P_m L A n k}{60}$$

$$= \frac{500 \times 0.12 \times \frac{\pi}{4} \times 0.09^2 \times 600 \times 4}{60} = 15.268\ kW.$$

$$BP = IP \times \eta_m = \cancel{0.7}\ 15.268 \times 0.75 = 11.451\ kW$$