THERMODYNAMICS

DEC – 17

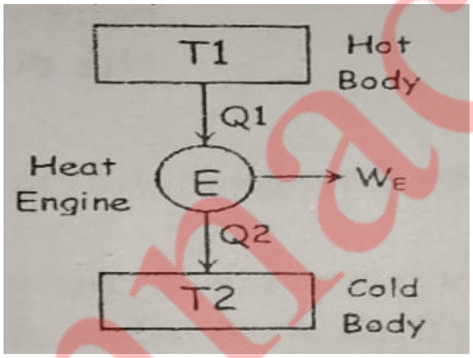
Q.1(a) Define heat engine, refrigerator and heat pump. [5]

Ans: Heat engine: It is a device which is operated in cycle it receives energy from high temperature body, converts part of it into work and rejects rest to a low temperature body.

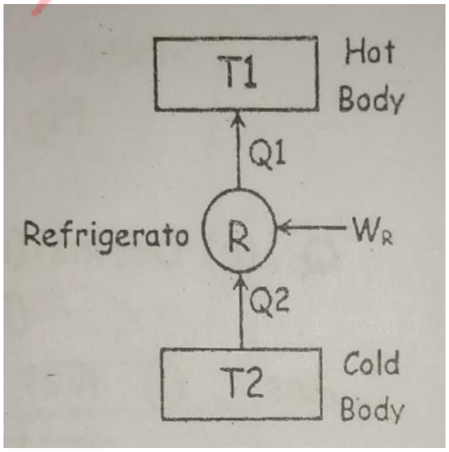
The primary objective of heat engine is to convert the energy as heat into work. E.g. Thermal power plant.

Efficiency of heat engine: The efficiency of a heat engine is defined as the ratio of the Net work done to the energy absorbed as heat.

$$n_E = \frac{output}{Input} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = (T_1 - T_2)/T_1$$



Refrigerator: refrigerator is cyclically operated device which absorb energy as heat from low temperature body and rejects energy as heat To a high temperature body when the work is performed on the device. The primary objective of a device is to maintain body at low temperature.



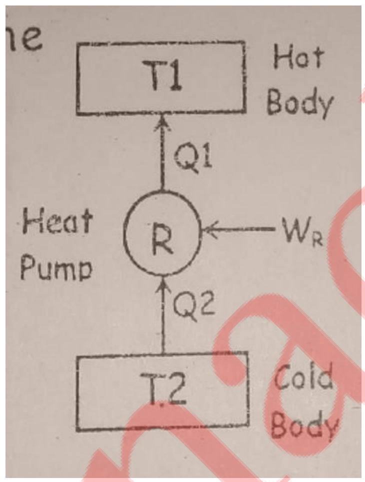
Fig

C.O.P of refrigerator: the cop of refrigerator is defined as the ratio of the heat absorbed to the work done.

$$COP_R = \frac{Output}{input} = \frac{Q_2}{W} = \frac{Q_2}{Q_2 - Q_1} = \frac{T_2}{T_2 - T_1}$$

Heat pump: Heat pump is a cyclically operated device which absorb energy from a low temperature body and reject energy as heat to a high temperature body. The main objective of the heat pump is to reject energy as heat to a high temperature reservoir.

$$COP_H = \frac{Output}{input} = \frac{Q_2}{W} = \frac{T_2}{T_2 - T_1}$$



Fig

Cop of heat pump: The cop of heat pump is defined as the ratio of the heat supplied to the work done

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Q.1(b) Draw a neat diagram of vane type blower and explain its working. [5]

Ans: 1) Vane type compressor refer figure consists of a rotor mounted eccentrically in the body and supported by ball and roller bearing at the ends.

2) The rotor is slaughtered to take the blades which are of a non-metallic material usually fibre or carbon. Each blade moves past the Indian passage compression begins due to decreasing volume between the rotor and casing.

3) Delivery begins with the arrival of each blade at the delivery passage. PV diagram is shown in the figure b where V induced volume at state P_1 n T_1. Compression occurs to the pressure P_1 isentropic ally. At this pressure the displays gas is open to the receiver and the gas flowing back

from the receiver rises the pressure irreversibly to p_2. The work input is given by the sum of areas a and b.

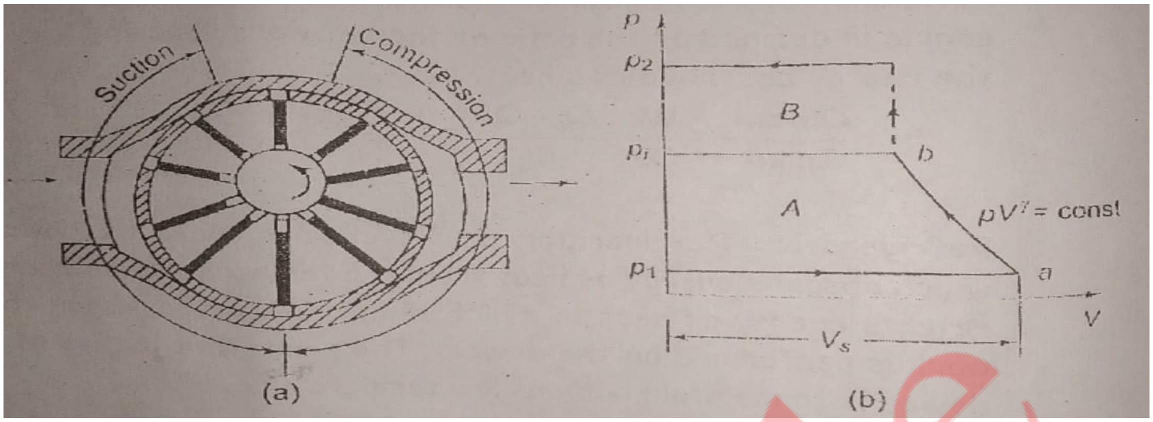


Fig: vane type positive displacement compressor with PV diagram.

Q.1(c) Define 1) wet steam 2) superheated steam 3) dryness fraction 4) saturation temperature [5]

Ans**: 1) wet steam**: The steam in the steam space of a boiler generally contains water mixed with it in the form of a mist (fine water particles). Such a steam is termed as wet steam.

2)Superheated steam: if the water is entirely evaporated and further heat is then supplied the first effect on the steam is to make it dry if it is not already dry the temperature of steam will then begin to increase with the corresponding increase in volume.

steam in this condition heated out of contact with water is said to be superheated. Superheating is assumed to take place at constant pressure the amount of superheating is measured by the rise in temperature of the steam above its saturation temperature T_S greater the amount of superheating the more will the steam acquire the properties of a perfect gas.

3) Dryness fraction: The quality of steam as regards iTs dryness is termed as dryness fraction.

Dryness fraction is usually expressed by the symbol 'x'.

Dryness fraction is often spoken as a quality of wet steam.

If M_s = mass of dry steam contained in the steam considered

M = mass of water in suspension in the steam considered.

$X = \frac{M_S}{M_S+M}$

Thus, if dryness fraction of wet steam x = 0.8 then 1 kg of wet steam contains 0.2 kg of moisture (water) in suspension and 0.8 kg of dry steam.

4) saturation temperature: It is the maximum temperature corresponding to a given pressure at which a substance can exist in liquid form.

when a liquid and its vapour are in equilibrium at a certain pressure and temperature, only the pressure of the temperature is sufficient to identify the saturation state.

If the pressure is given the temperature of the given fixture get fixed, which is known as **saturation temperature.**

Q.1(d) what do you understand by mean temperature of heat addition? For a given temperature of heat rejection show how the Rankine cycle efficiency depends on the main temperature o the heat addition. [10]

Ans: In the Rankine cycle heat is added reversibly at constant pressure but at infinite temperatures.

If Tm_1 is the mean temperature of heat addition, as shown in the figure show that area under 4S and 1 is equal to the area under 5 and 6, then heat added.

$Q = h_1 - h_4 = T_{m1} (S_1 - S_4)$

T_{m1} = mean temperature of heat addition

$$= \frac{h_1 - h_{4_S}}{s_1 - s_{4_S}}$$

Since Q_2= Heat rejected = $h_{2S} - h_3$

$= T_2 (S_1 - S_{4S})$

Efficiency of Rankine $\eta_{Rankine} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2(S_1 - S_4)}{T_{M1}(S_1 - S_4)}$

$$\eta_{Rankine} = 1 - \left(\frac{T_2}{T_{ML}}\right) \quad (1)$$

Where T_2 is the temperature of heat rejection. Then lower is the T_2 for a given T_{M1}, the higher will be the efficiency of Rankine cycle. But the lowest practicable temperature of heat rejection is the temperature of the surroundings T_0. This being fixed.

Efficiency of Rankine. = $F(T_{M1})$ only

The higher the mean temperature of heat addition, the higher will be the cycle efficiency.

Q.1(e) state the first law for a closed system undergoing a change of state. [5]

Ans: The expression (W)cycle= $(Q)_{CYCLE}$ applies only to the system undergoing cycles and algebraic summation of all energy transfer across system boundaries is zero.

But if a system undergoes a change of state during which both heat transfer and work transfer are involved, the net energy transfer will be sorted or accumulated within the system.

If Q is the amount of heat transfer to the system and W is the amount of work transfer from the system during the process figure 1, the net energy transfer (Q-W) will be sorted in the system.

Energy in storage is neither heat nor work energy given the name internal energy or simply energy system.

Therefore, $Q - W = \Delta E$

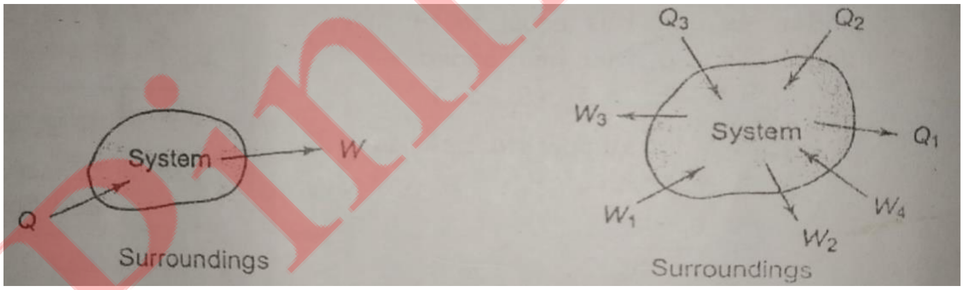
Where E is the increase in the energy of the system

Or $Q = \Delta E + W$ (1)

Near Q, W and ΔE are all expressed in the same units in joules energy may be sorted by a system in different modes.

If there are more energy transfer quantities involved in the process as shown in figure 2, the first law gives,

$(Q1_2+Q_3-Q_1) = \Delta E + (W_2+W_3-W_1-W_4)$



Energy is conserved in the Operation. The first law is a particular formulation of the principle of the conservation of energy.

Equation 1 may be also considered as the definition of energy. This definition does not give an absolute value of energy E, but only the change of energy for the process. It can however be shown that the energy has a definite value at every state of no system and is therefore a property of the system.

Q.2(a). Reciprocating air compressor text in 3 m^3/min 0.11 MPa, 20°C which it delivers at 1.5 MPa, 111° C to an after cooler where the air is cooled at constant pressure to 25°C. The power absorbed by the compressor is 4.15 KW. Determine the heat transfer in the compressor and the after cooler. [10]

Ans:. V_1 = 2 m^3/min= 2/60 = 0.33 m^3/s

P_1 = 0.11 MPa P_2 = 1.5 MPa

T_1 = 20°C T_2 = 111°C T_3 = 25°C

Power absorbed by the compressor W = 4.15 KW

Mass flow rate of air using ideal gas equation

P_1V_1 = m R T_1

110 x 0.033 = m x 0.287 x 293

M = 0.0432 to kg/s

Applying steady flow energy equation at compressor

Q+m $h_1 + \left(\frac{V_1^2}{2000}\right) + gz_1 = w + m\ (h_2 + \left(\frac{V_2^2}{2000}\right) + gz_2$

Here KE= PE= 0

Q= m (h_2 – h_1) + W

= W+ m CP (T_2-T_1)

= (4.15) + (0.04 32 x 1.005 (384 – 293)

= 8.10 KW

Applying steady flow energy equation at aftercooler

Q+ m $h_2 + \left(\frac{V_2^2}{2000}\right) + gz_2 = w + m\ (h_3 + \left(\frac{V_3^2}{2000}\right) + gz_3$

Your KE = PE= W = 0

Q= m (h_3 – h_2)

= m Cp (T_3 –T_2)

= 0.04 32 x 1.005 x (298 – 384)

Q = -3.73 KW

Q.2(b) Derive the first and second TDS equation **[5]**

Ans: The TDS equations:

Consider the entropy S as a function of temperature and volume: s = s (T, V) :

Ds = $\left(\frac{\partial s}{\partial T}\right)_V \ dT + \left(\frac{\partial s}{\partial v}\right)_r \ dv$

We apply the definition of the heat capacity to the first term and Maxwell reaction to the second and obtain.

Ds =$\frac{Cv}{T} dT + \left(\frac{\partial P}{\partial T}\right)_T \ dv$

Tds = $Cv\ dT + T\ \left(\frac{\partial P}{\partial T}\right)_v \ dv$ (first Tds equation)

The second TDS equation follow the considering as a function of temperature and pressure : s = s (T,P) :

Ds == $\left(\frac{\partial s}{\partial T}\right)_p \ dT + \left(\frac{\partial s}{\partial P}\right)_r \ dP$

We again use the definition of heat capacity and Maxwell relation to obtain

Ds = $= \frac{Cp}{T} dT - \left(\frac{\partial V}{\partial T}\right) \quad dP\ o$

Tds = $C_p\ dT - T\ \left(\frac{\partial V}{\partial T}\right)_p \ dp$ (secondary Tds equation)

In summary,

Tds = Cv dT + T $\left(\frac{\partial P}{\partial T}\right)_V dv$

Tds = Cp dT – T $\left(\frac{\partial V}{\partial t}\right)_p dp$

TDS equation are frequently useful in deriving relationship among various thermodynamics derivatives.

Q.2(c) A lamp of 800 kg of steel at 1250 k is to be cooled 500 k. If it is desired to use the steel as source of energy, calculate the available and unavailable energy. Take specific heat of steel at 0.5 kJ/kg K and ambient temperature 300 K. **[5]**

Ans: Change in entropy of steel

$\Delta S = M\,.Cp\,.\ln\left(\frac{T_2}{T_1}\right)$ = 800 x 0.5 x ln (500/1250) **= -36.5 16 kJ/k**

- Available energy = Q – T_0 (ΔS)
  = M Cp (T_1- T_2) – T_0 (ΔS)
  = 800 x 0.5 x (1250 – 500) – (300 X 36.516)
  = 19 0.045 mJ
- Unavailable energy = T_0 (ΔS) = 300 X 36.5 16

  = 109.95 mJ

Q.3 (a)A heat pump working on a Carnot cycle takes in heat from a reservoir at 5°C and delivers heat to reservoir at 60°C. The head pump is driven by a reversible heat engine which takes in lead from a reservoir at 840 and rejects heat reservoir at 60°C. Reversible heat engine also drives a machine that absorbs 30 KW. If the pump extract 17 kJ/s from the 5°C reservoir, determine :

1) the rate of heat supply from 840°C source

2) the rate of heat rejection at 60°c sink. **[10]**

Ans: we know Carnot c o p of heat pump

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

= $\frac{333}{333-278}$

= 6.055

ALSO C.O.P = $\frac{heat\ rejected}{work\ supplied}$

6.055 = $\frac{Q_R}{Q_R - Q_S} = \frac{Q_R}{Q_R - 17}$

Q_R = 20.195 kW

Applying first law at heat pump

Heat supplied = heat rejected

Wnet + Q_S = Q_R

Wnet = Q_R + Q_S = 20.1 97 – 17 **= 3.195 kW**

Now the total work output of reversible heat engine

= (W net to heat pump) + (W net to external machine)

= 3.1 95 + 30 **= 33.1 95 KW**

Now efficiency of reversible heat engine is given by

$\eta_{HE} = \frac{T_1 - T_2}{T_1} = \frac{1113-333}{1113} = 0.7008 = 70.08\ \%$

Also $\eta_{HE} = \frac{Q_S - Q_R}{Q_S}$

$0.7\ 008 = \frac{33.195}{Q_S}$

Q_S = 47.37 KW

Q_S - Q_R = W Net

Qr = Qs – Wnet

= 47. 37 – 33. 195

= 14.175 KW

Total heat rejected

= $(Q_R)_{HP}$ +$(Q_R)_{HE}$

=14.175 + 20.195

=3 4.37 Kw

Q.3 (b) determine entropy change of universe, if two copper blocks of 1 kilogram and 0.5 kilogram at 150°C and 0°C joined together. Specific heats for copper at 150°C and 0°C are 0.393 kJ/kg and 0.38 1 kJ/kg K respectively. [5]

Ans : Here ΔS universe = ΔS block 1 +ΔS block 2

Two blocks at different temperatures shall first attain equilibrium temperature. Let equilibrium temperature be T_F

1 x 0.39 3 x (42 3.15 – T_F) = 0.5 x 0.381 x (T_S x 273.15)

T_F = 37 4.19 k

Entropy change in block 1 due to temperature changing from 423.15 k to 2374.19 k

$\Delta S1 = 1 \text{ x } 0.393 \text{ x } \ln\left(\frac{374.19}{423.15}\right) = -0.0483\ kj/k$

Entropy change in block 2

$\Delta S2 = 0.5 \text{ x } 0.381 \text{ x In}\left(\frac{374.19}{273.15}\right)$

= 0.0 599 kJ/k

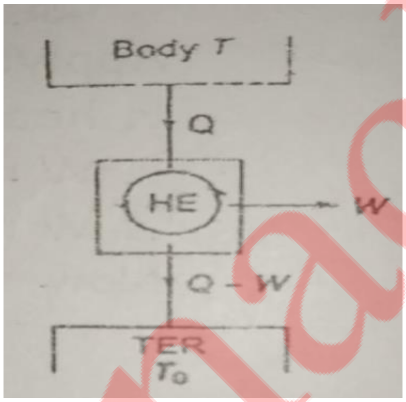
Entropy change of universe

ΔS universe = ΔS1 + ΔS2 = 0.05 99 - 0.04 83

= 0.0116 kJ K

Q.3(c) determine the maximum work obtainable by using of finite body at temperature t and thermal energy reservoir at temperature T0, T > T0 [5]

Ans : let one of the body is consider in the previous section b a thermal energy reservoir.



The finite body and body has a thermal capacity CP and is at temperature T and TER is at temperature T, Such that T > T0.

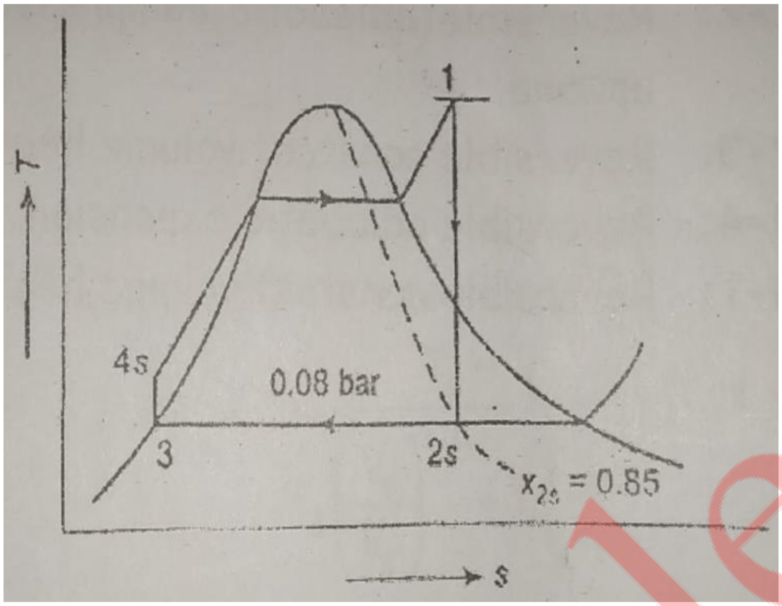
Let a heat engine operates between the two refer figure. is withdrawn from the body is temperature decreases. the temperature of the TER would however remain unchanged at T0

Danger full stop working in the temperature of the body reaches to T0. During that period the amount of work deliver is w, and heat rejected to the t e r is (Q-W).

Then It is called energy of the finite body at temperature T.

Q.4(a) cycle steam power plant is to be designed for a steam temperature at turbine inlet of 360° and exhaust pressure of 0.08 bar. After isentropic expansion of steam in the turbine the moisture content determine exhaust is not to exceed 15%. Determine the greatest allowable steam pressure and turbine inlet and calculate the Rankine cycle efficiency for this steam conditions. Estimate also the mean temperature of heat addition. [10]

Ans: as state 2s (refer figure) quality and pressure are known



$S_{2s} = S_f + X_{2s} S_{fg}$

$= 0.5926 + 0.85 (8.2 287 - 0.5926)$

$=7.0833$ kJ/kg k

Since $s_1 = S_{2s}$

$S_1 = 7.0833$ kJ / kg k

At state 1, the temperature and entropy are thus known. At 360°C $S_g = 5.0526$ kJ / kg k which is less than S1. So from the table of superheated steam at $T_1 = 360$ and $S_1 = 7.0 833$ kJ/kg k the pressure is found to be 16.832 bar (by interpolation).

The greatest allowable steam pressure is

P_1= 16.8 32 bar

H_1 = 316 5.54 kJ/kg

H_{2s} = 17 3.88 + 0.85 X 240 3.1 = 2216.52 kJ/kg

H_3 = 173.8 kJ/kg

$H_4 - H_3$ = 0.001 x (16.83 - 0.08) X 100 = 1.675 kJ / kg

H_{4s} = 17.5 61 kJ/kg

Q1 = h_1- h_4 = 316 5.5 4 – 17 5.56 = 2990 kJ/ kg

$W_t = h_1 - h_{2s}$ = 316 5.5 4 - 221 6.52 = 949 kJ / kg

W_p= 1.675kJ/kg

$N_{cycle} = \frac{w_{net}}{Q_1} = \left(\frac{947.32}{2990}\right) = 0.3168$

Mean temperature of heat addition

$T_{m1} = \frac{h_1 - h_{4s}}{s_1 - s_{4s}} = \frac{2990}{7.0833 - 0.5296} = 460.66\ k = 187.51°C$

Q.4(b) derive an expression for air standard efficiency for Otto cycle. [10]

Ans : Otto cycle: the main drawback of carnot cycle is its impractically due to high pressure and high volume ratio employed with comparatively low mean effective pressure.

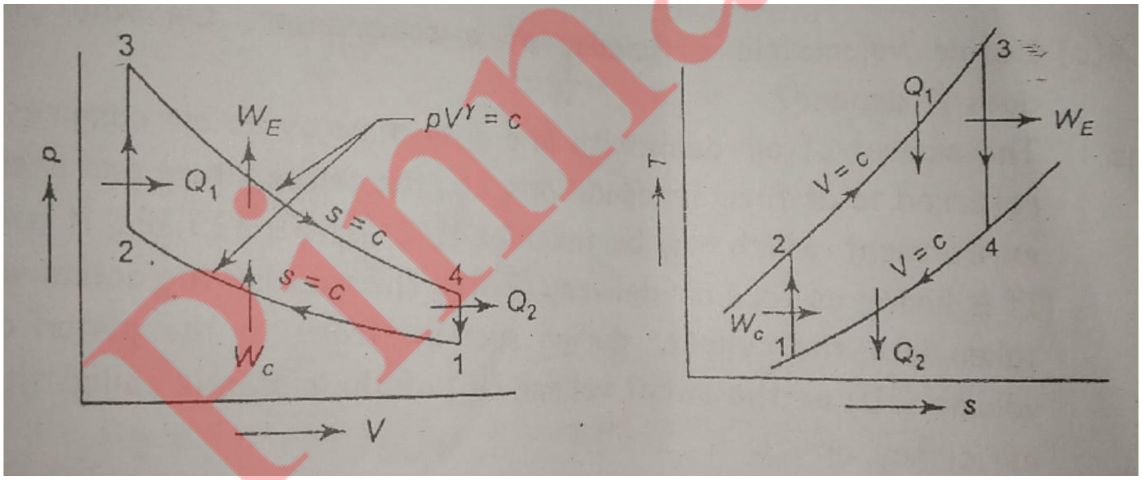
Nicholas auto 1876 first propose a constant volume heat addition cycle which forms a basis for working of today's spark ignition engines.

Process 1 to 2 : reversible adiabatic compression of air when piston moves upward.

Process 2 to 3 : reversible constant volume heat addition

Process 3 to 4 : reversible adiabatic expansion

Process 4 to 1 : reversible constant volume heat rejection.



Air standard efficiency:

Compression ratio: it is defined as the ratio of volume at the beginning of the compression to the volume at the end of the compression.

$r_K = \frac{volme\ at\ the\ begining\ of\ the\ compression}{volume\ at\ the\ end\ of\ the\ compression} = \left(\frac{V_1}{V_2}\right)$

Thermal efficiency of Otto cycle can be written as

$\eta_{OTTO} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$

Let m be the fixed mass of air undergoing the cycle,

Heat supplied, $Q_{(2\text{-}3)} = Q_1 = m\,C_v.\,(T_3 - T_2)$

Heat rejected, $Q_{(4\text{-}1)} = Q_2 = m\,C_v.\,(T_4 - T_1)$

Insufficiency can be given as

$\eta_{otto} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{m.C_v.(T_4-T_1)}{m.C_v.(T_3-T_2)} = 1 - \frac{T_4-T_1}{T_3-T_2}$ V

Process 1 to 2, $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{r-1}$

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

Process 3 to 4, $\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{r-1} = \left(\frac{V_1}{V_2}\right)^{r-1}$

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

Putting the value of T2 and T3 in equation 1

$$\boldsymbol{\eta_{OTTO} = 1 - \frac{T_4-T_1}{T_3-T_2} = 1 - \frac{T_4-T_1}{T_4\left(\frac{V_1}{V_2}\right)^{r-1} - T_1\left(\frac{V_1}{V_2}\right)^{r-1}} = 1 - \frac{1}{r_K^{r-1}}}$$

Q.4(c) Define volumetric efficiency of a compressor. On what factors does it depend? [5]

Ans: The amount of air deals with in a given time by an air compressor is often referred at free air conditions, eg the temperature and pressure of the environment which made taken as 15°C and 101.325 KPa, if not mentioned.

It is known as free air delivery (FAD). The ratio of the actual volume of gas taken into the cylinder during suction stroke to the piston displacement volume of the swept volume (vs) of the piston is called volumetric efficiency, or

$\eta_{vol} = \frac{mv_1}{PD} = \frac{mv_1}{v_s}$

Where m is the mass flow rate of the gas and v1 is the specific volume of the gas inlet to the compressor. Reference to figure 1.

$\eta_{vol} = \frac{V_2-V_1}{V_S} = \frac{V_C+V_S-V_1}{V_S}$

$= 1 + \left(\frac{V_C}{V_S}\right) - \left(\frac{V_1}{V_S}\right)$

Let C = clearance = $\frac{CLEARANCE\ VOLUME}{PD\ or\ V_s}$

$= \frac{V_C}{V_S}$

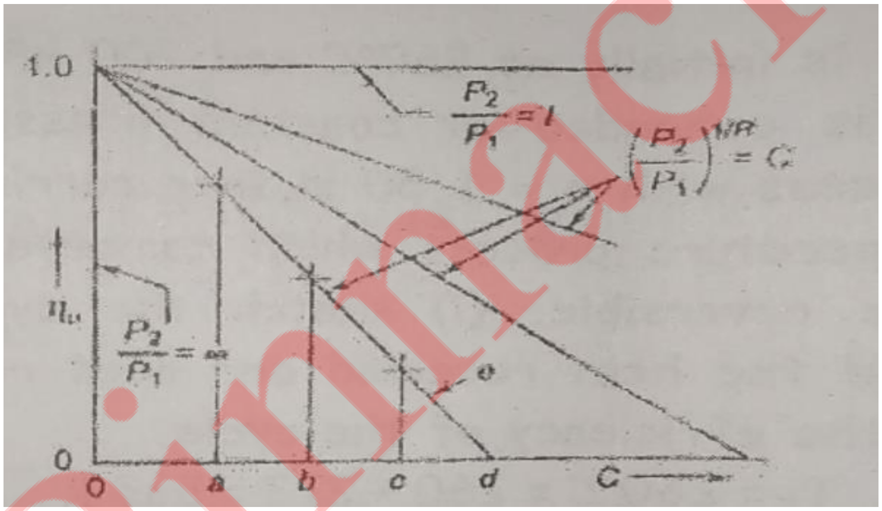
Since $P_1V_1^n = P_2V_4^n$

$$v_1 = v_4\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}} = v_c\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$$

$$\eta_{vol} = 1 + C - \left(\frac{v_c}{v_s}\right)\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$$

$$= 1 + C - C\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}} \quad (1)$$

Equation 1 plotted in figure 2 two Sins (p2/p1) is always greater than unity, it is evident that the volumetric efficiency decrease as a clearance increases and as the pressure ratio increases.



In order to get maximum flow capacity, compressor are built with the minimum practical clearance. Sometimes however the clearance is deliberately increase ($m = \frac{v_s n_v}{v_1}$) as a means of controlling the flow through a compressor driven by a constant speed motor.

The compressor cylinder in figure is fitted with the clearance pocket which can be opened by a valve.

Let us suppose that this machine is operating at conditions corresponding to line in figure if the clearance volume is at minimum value at the volumetric efficiency and flow through the machine are maximum.

Clearance pocket is then opened to increase a clearance to b, the volumetric efficiency and the flow are reduced. By increasing the clearance in steps as indicated by point c and d, the flow may be reduced in steps to zero

The work per kilogram of gas compressed is, however, not affected by the clearance volume in an idealized compressor.

For a given pressure ratio n is zero when maximum clearance is

$$C_{max} = \frac{1}{\left(\left(\frac{p_2}{p_1}\right)\right)^{\frac{1}{n}} - 1}$$

Following factors affect the volumetric efficiency of air compressor:

1) Clearance between the piston of TDC and cylinder cover. Larger the clearance lesser the air discharge per stroke and lesser will be the volumetric efficiency of air compressor.
2) Sluggish operation of valves.
3) Lealcy piston rings
4) Ineffective cooling due to choking of inter after cooler for lack of water supply.
5) High temperature of air at suction of 1^{st} stage and dirty air filters.

Q.5(a) A mass of air is initially at 260°C and 700 kPa and occupies 0.028 m^3. The air is expanded at constant pressure to 0.084 m^3. Polytrophic process with n is = 1.50 is then carried out, followed by a constant temperature process which completes the cycle. All the process is reversible [10]

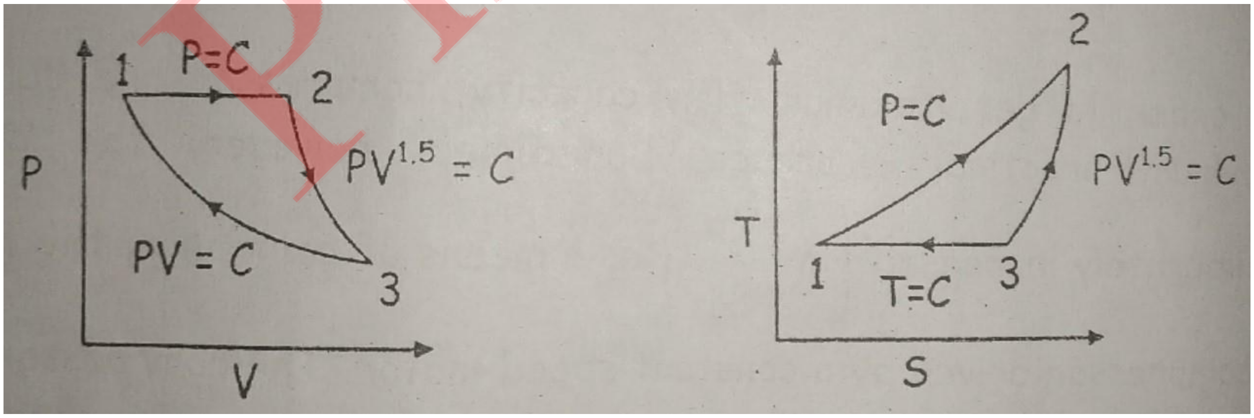
1) sketch the cycle on PV and TS plane.

2) find the heat received and heat rejected in the cycle

3) find efficiency of the cycle.

Ans : P_1 = 700 Kpa T_1 = 260 + 273 = 533 k

V_1 = 0.028 m V_2 = 0.084 m3



We have $P_1V_1 = mRT_1$

m = $\frac{700\times0.028}{0.287\times533} = 0.128$ kg

now, $\frac{T_2}{T_1} = \left(\frac{p_2v_2}{p_1v_1}\right) = \left(\frac{0.084}{0.027}\right) = 3$

therefore $T_2 = \ 3 \times 533 = 1559$ k

Again $\frac{p_2}{p_3} = \left(\frac{T_2}{T_3}\right)^{\frac{n}{n-1}}$

= $\left(\frac{1599}{533}\right)^{\frac{1.5}{0.5}} = 3^3 = 27$

$p_3 = \left(\frac{p_2}{27}\right) = \left(\frac{700}{27}\right) = 25.93\ kpa$

Heat transfer in process 1 to 2

$Q_{1-2} = mC_P(T_2 - T_1)$

$=0.128 \times 1.005(1599 - 533)$

=137.13 KJ

Heat transfer in process 2-3

$Q_{2-3} = \Delta U + \int Pdv$

$= mC_v(T_3 - T_2) + \frac{mR(T_2-T_3)}{n-1}$

$Q_{2-3} = m\ C_v\frac{n-y}{n-1}(T_3 - T_2)$

$Q_{2-3} = 0.128 \times 0.718 \times \frac{1.5-1.4}{1.5-1}.(533 - 1599)$

= -19.59 Kj

Process 3-1

$Q_{3-1} - dU + w_{3-1}$

But Du = 0 – (ISOTHERMAL PROCESS)

$W_{3-1} = \int_3^1 pdv = mRT_1\ In\ \left(\frac{v_1}{v_3}\right) = mRT_1\ In\ (\frac{p_3}{p_1})$

$=0.128 \times 0.287 \times 533 \times Ln\ (\frac{25.93}{700})$

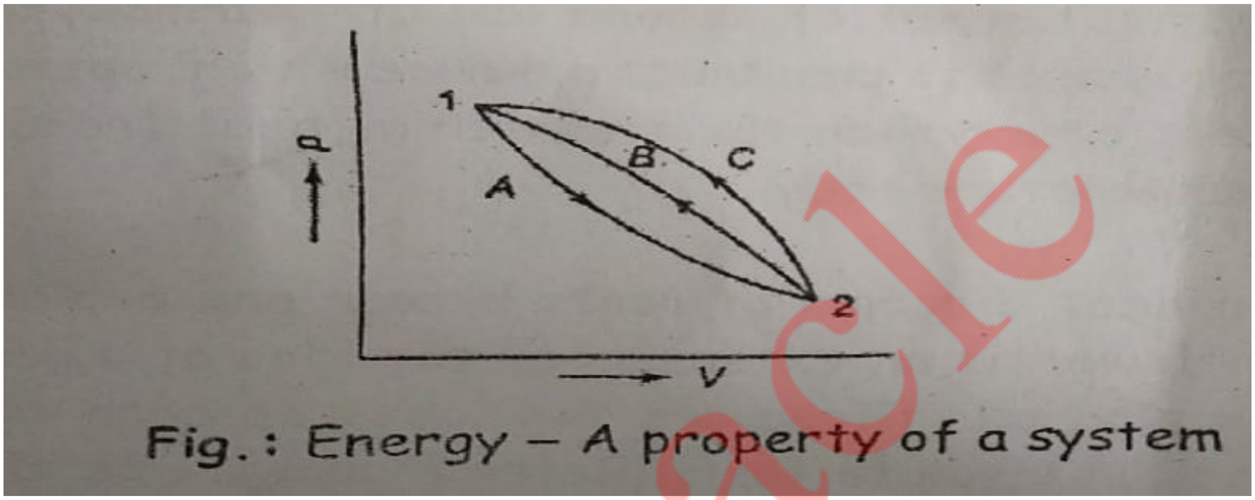
= -64.53 kJ

1) Heat received in the cycle Qs = 137.13 = kJ
2) Heat rejected in the cycle QR = 19.5 9 + 64.5 3 = 84.12 lJ
3) Efficiency of the cycle

$$\eta_{cycle} = \frac{Q_s - Q_r}{Q_s} = \frac{137.13 - 84.12}{137.13} = 38.66\%$$

Q.5(b) Q.1(c) show that energy is a property of a system. **[5]**

Ans: Energy - A property of a system



Fig(a)

Consider a system which changes its state from state 1 to state 2 by following the path A, and the returns from state 2 to state 1 by following the path B (refer fig (a)). so the system undergoes a cycle. Writing the first or path A

$Q_A = \Delta E_A + W_A$ (1)

For path

$Q_B = \Delta E_B + W_B$ (2)

The process A and B together constitute a cycle, for which

$(\sum W)_{CYCLE} = (\sum Q)_{CYCLE}$

OR $W_A + W_B = Q_A + Q_B$

OR $Q_A - W_A = W_B - Q_B$ (3)

From eq (1), (2) and (3) its yields

$\mathbf{\Delta E_A = -\Delta E_B}$ (4)

Similarly, had the system returned from the state 2 to state 1 but following the path C instead of path B

$\Delta E_A = -\Delta E_C$ (5)

From eq (4) and (5)

$\Delta E_B = \Delta E_C$ (6)

Therefore, it is seen that the change in energy between two states of a system is the same, whatever the path the system may follow in undergoing that change of state. If some arbitrary value of energy is assigned to state 2 the value of energy at state 1 is fixed independent of the path the system follows. Therefore, energy has a definite value of energy state of the system. Hence it is a point function and a property of the system

The energy E is an extensive property. The specific energy, e = E/m (j/kg). is an extensive property.

The cyclic integral of any property is zero, because the final state is identical with the initial state.

Q.5(c) Write Maxwell's equations. **[5]**

Ans: A pure substance existing in single phase has only two independent variables of the 8 quantities P, V, T, S, U, H, F (Helmholtz function|) and G (Gibbs function) anyone may be expressed as a function of any two others.

If dz = m. dx + N. dy then, $\left(\frac{\partial M}{\partial Y}\right)_X = \left(\frac{\partial N}{\partial X}\right)_Y$

For a pure substance undergoing an infinitesimal reversible process,

1. dU = T. dS – p. dV
   since U is thermodynamic property of exact differentials.
   $$\left(\frac{\partial T}{\partial V}\right)_s = \left(\frac{\partial p}{\partial S}\right)_V$$
2. dH = dU + p. dv + V. dp = T. ds + V. dp
   since H Is thermodynamics property of exact differentials,
   $$\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial v}{\partial S}\right)_P$$
3. dF = dU-T. dS – S. dT = -P. dV – S. dT
   since F is the thermodynamics property of exact differentials,
   $$\left(\frac{\partial p}{T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$
4. dG = dH – T. dS – S. dT = V. dp – S. dt
   Since G is the thermodynamics property of exact differentials,
   $$\left(\frac{\partial V}{\partial T}\right)_P = \left(\frac{\partial S}{\partial p}\right)_T$$

Q.6(a) An Air standard limited pressure cycle has a compression ratio of 15 and compression begins at 0.1 MP a 40° C. The maximum pressure is limited to 6 mpa and the heat added is 1.675 MJ/kg. [10]

Compute: 1) the heat supplied at constant volume in kJ/kg

2) heat supplied at constant pressure in kJ /kg

3) the work done per kg of air,

4) the cycle efficiency and

5) the m.e.p of the cycle

Ans:

Compression ratio $r_c = \left(\frac{v_1}{v_2}\right) = 15$

Inlet pressure = 0.1 mpa = 1 bar

Initial temperature T1 = 40 °C = 40+ 273 = 313 k

Maximum pressure in cycle $P_3 = P_4$ = 6mpa = 60 bar

Total heat added = Qs = 1.675 mJ/kg = 1.675 x 10^3

Process 1-2: Isentropic compression process

$$\left(\frac{v_1}{v_2}\right)^{r-1} = \left(\frac{T_2}{T_1}\right) = (15)^{1.4-1} = \frac{T_2}{313} = 924.66\ k$$

$$T_2 = 924.66\ k$$

Similarly $\left(\frac{p_2}{p_1}\right)^{\frac{r-1}{r}} = \left(\frac{v_1}{v_2}\right)^{r-1}$

$$p_2 = (1.5)^{1.4} \times 10_5 = 44.313\ bar$$

Pressue ratio $(r_p) = \frac{p_3}{p_2} = \frac{60}{44.313} = 1.354$

Process 2-3: $\frac{p_2}{T_2} = \frac{p_3}{T_3}$

$$\left(\frac{44.313}{924.66}\right) = \frac{60}{T_3}$$

$$T_3 1252\ k$$

Total heat supply Qs $=(Q_s)_{v=c} + (Q_s)_{p=c}$

$$(1.675 \times 10^3) = C_v(T_3 - T_2) = c_p(T_4 - T_3)$$

$\boldsymbol{T_4 = 26979.83\ k}$

Process 4-5: $\frac{V_3}{V_4} = \frac{T_3}{T_4}$

$\frac{V_3}{V_4} = \left(\frac{1252}{2679.83}\right) = 0.467$

$\boldsymbol{cut\ offratio\ (s) = \left(\frac{V_4}{V_3}\right) = 2.14}$

Process 5-1 :

We know that r_e = expansion ratio = $\frac{V_5}{V_4}$

$r_e = \frac{V_5}{V_4} = \frac{r_c}{s} = \frac{156}{2.14} = 7$

$r_e = \frac{V_5}{V_4} = 7$

Now, $\left(\frac{V_5}{V_4}\right)^{(1.4-1)} = \left(\frac{T_5}{T_4}\right)$

$T_S = \left(\frac{2679.83}{(7)^{0.4}}\right) = 1230.46\ K$

Heat supplied at constant volume

$(Q_S)_{V=C} = c_V(T_3 - T_2) = 0.718(1252 - 924.66)$

= 235.03KJ/KG

Heat supplied at constant pressure

$(Q_S)_{P=C} = c_P(T_4 - T_3) = 1.005(2673.83 - 1252)$

= 1434.97 KJ/KG

Work done: $(Q_S)_{V=C} + (Q_S)_{P=C} - (Q_R)_{V=C}$

Heat rejected

$(Q_R)_{V=C} = C_V(T_5 - T_1) = 0.718(1230.46 - 313) = 658.736\frac{KJ}{KG}$

$W.D = (235.03 + 1434.97) - (658.736)$

$\boldsymbol{W.D = 1011.264\ KJ/KG}$

Cycle efficiency: $\frac{WD}{Q_S}$

$\frac{\mathbf{1011.264}}{\mathbf{1.675 \times 10^3}} = \mathbf{0.6037}\%$

MEP: $P_1\left[Y.r_p.r_c^{y}(\rho-1)+r_c^{y}\left(r_p-1\right)-r_c\left(r_p.\rho^{y}-1\right)\right]/(\gamma-1)\times(r_c-1)$

$=(10^5)[1.4\times1.354\times15^{1.4}(2.14-1)+15^{1.4}(1.354-1)-1.5(1.354\times2.14^{1.4}-1)]/$
$(1.4-1)\times|(15-1)$

= 18.756 bar

Q.6 (b) single stage double acting air compressor is required to deliver 14 mm of air per minute measured at 1.013 bar and 15 C. The delivery pressure is 7 bar and the speed 300 rev/min. Take the clearance volume at 5% of the swept volume with compression and re expansion index of n = 1.3.

Calculate the swipe volume of the cylinder delivery temperature and the indicated power. [10]

Ans : swept volume, $v_s = v_a - v_c$

Here $v_a = 1.05\ v_s$

$v_c = 0.05\ v_s$

Volume induced cycle per cycle

$(v_a - v_d) = 14\ m^3/min$

$$= (\frac{14}{300\left(\frac{rev}{min}\right)\times2} = 0.023m^3/cycle$$

We know, $\frac{v_d}{v_c} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$

$v_d = v_c\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}} = 0.05v_s\left(\frac{7}{10.13}\right)^{\frac{1}{1.3}}$

$v_d 0.221\ v_s$

$(v_a - v_d) = 10.05\ v_s - 0.221\ v_s$

= 0.8288 v$_s$

From 1we get

$0.8288\ v_s = 0.023$

$\boldsymbol{v_s = 0.028m^3}$

Swipe volume $(v_s)0.0285\ m^3$

We also have

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

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

$$= 288 \left(\frac{7}{1.013}\right)^{\frac{0.3}{1.3}}$$

$$t_2 = 4502\ k$$

Delivery temperature T_2 = 450 k

Indicated power (IP)

$$IP = \left(\frac{n}{n-1}\right) p_1 v \left\{\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right\}$$

$$\left(\frac{1.3}{1.3-*1}\right) \times 1.013 \times 10^5 \left\{\left(\frac{7}{1.013}\right)^{\frac{0.3}{1.3}} - 1\right\}$$

= 5758.52 W

IP = 57.58 kw