

total marks 238

(3ha)

Total marks	
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Q1(a)

$$P = 1 \text{ kN} = 1000 \text{ N}$$

$$S_{yt} = 380 \text{ N/mm}^2$$

$$FOS = 2$$

$$(MSS T) \dots (d) = ?$$

$$M = (\text{moment}) = P \times 250 \\ = 1000 \times 250 = 250 \times 10^3 \text{ Nmm}$$

$$T = (\text{torque}) = P \times 50 = 1000 \times 50 \\ = 50 \times 10^3 \text{ Nmm}$$

$$\sigma_b = \frac{32M}{\pi d^3} = \frac{32 \times 250 \times 10^3 \text{ Nmm}}{\pi d^3} \\ = \frac{2546479.089}{d^3} \text{ (N/mm}^2\text{)}$$

$$\tau = \left(\frac{16T}{\pi d^3} \right) = \frac{16 \times 50 \times 10^3 \text{ (Nmm)}}{\pi d^3} \\ = \frac{2546479.089}{d^3} \text{ (N/mm}^2\text{)}$$

According to MSS T,

$$\tau_{max} \leq \tau_{per}$$

$$\sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2} \leq (\tau_{per})$$

$$\sqrt{\left(\frac{2546479.089}{d^3 \times 2}\right)^2 + \left(\frac{2546479.089}{d^3}\right)^2} \leq \tau_{per}$$

$$S_{yt} = 380 \text{ N/mm}^2$$

$$\tau_{per} = \left(\frac{0.5 \times S_{yt}}{FoS} \right) = \frac{0.5 \times 380}{2} = 95 \text{ N/mm}^2$$

$$\therefore \frac{2547050.173}{d^3} \leq 95$$

$$d = 31.061 \approx 32 \text{ mm}$$

the dia of shaft is 32mm

Q1 (c)

$$B = \begin{bmatrix} 0.707 & ? & 0 & 2 \\ ? & 0 & 1 & 4 \\ ? & -0.707 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

comparing B with

$$B = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\therefore p_x = 2, p_y = 4, p_z = 5$$

now, by using properties,

$$n_x^2 + n_y^2 + n_z^2 = 1$$

$$o_x^2 + o_y^2 + o_z^2 = 1$$

$$a_x^2 + a_y^2 + a_z^2 = 1$$

$$(0.707)^2 + (0)^2 + (-0.707)^2 = 1$$

$$\boxed{0.707 \ 0 \ 0.707}$$

$$4 \ (0.707)^2 + (n_y)^2 + (n_z)^2 = 1$$

$$n_y^2 + n_z^2 = 0.5$$

$$\vec{n} \times \vec{u} = \vec{a}$$



$$\vec{n} \times \vec{u} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0.707 & n_y & n_z \\ 0.707 & 0 & -0.707 \end{vmatrix}$$

$$= \hat{i}(-0.707 n_y - 0) - \hat{j}(-0.5 - n_z \cdot 0.707) + \hat{k}(0 - n_y \cdot 0.707)$$

$$= (-0.707 n_y) \hat{i} + (0.5 + 0.707 n_z) \hat{j} + (-0.707 n_y) \hat{k}$$

$$= a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$$

$$-0.707 n_y = 0 \implies \boxed{n_y = 0}$$

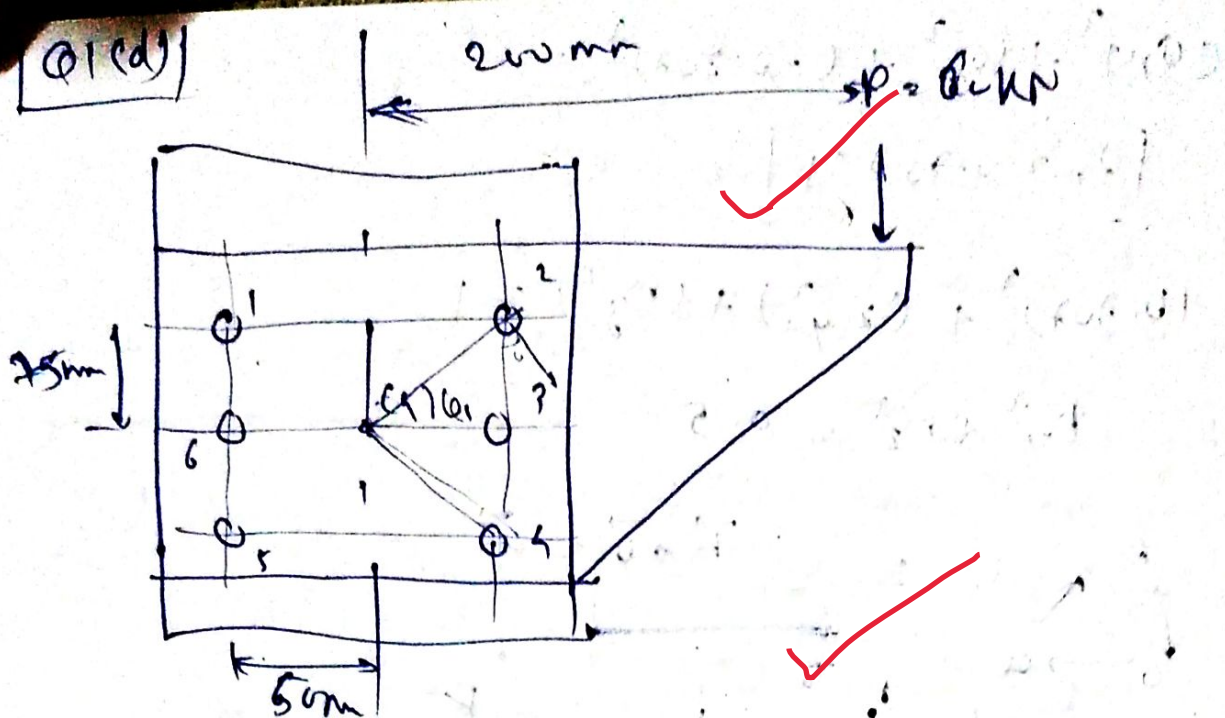
$$0.5 + 0.707 n_z = a_y = 1$$

$$\boxed{n_z = 0.707}$$

$$\therefore B = \begin{bmatrix} 0.707 & 0.707 & 0 & 2 \\ 0 & 0 & 1 & 4 \\ 0.707 & -0.707 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

one more possible solution, refer solution





$$(F_p) = \text{Primary shear force} = \frac{P}{6} = 10 \text{ kN}$$

F_s = secondary shear force

$$(F_s) = \frac{(P_p) \times r_i}{\sum r_i^2}$$

Now,

$$r_1 = \sqrt{25^2 + 50^2} = 90.1387 \text{ mm}$$

$$r_4 = r_2 = r_3 = r_5 = 90.1387 \text{ mm}$$

$$r_3 = r_6 = 50 \text{ mm}$$

$$\sum r_i^2 = (r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2) = 37500 \text{ mm}^2$$

$$(F_{s1} = F_{s2} = F_{s4} = F_{s5}) = \frac{60 \times 10^3 \times 200 + 90.1387}{37500} = 29863.524 \text{ N}$$

$$F_{s3} = F_{s6} = \frac{60 \times 10^3 \times 200 + 50}{37500} = 16000 \text{ N}$$

$$(\tan \theta_1) = \frac{75 \text{ mm}}{5 \text{ mm}} \Rightarrow \theta_1 = 56.3099^\circ$$

$$\therefore R_1 = \sqrt{F_p^2 + F_s^2} + 2F_p + F_s \cos \theta$$

$$R_1 = \sqrt{(10000)^2 + (28863.544)^2} + 2 \times 10000 \times 28863.544 \times \cos 56.3099^\circ$$

$$R_1 = 35402.2523 \text{ N} \quad \text{--- (1)}$$

$$R_2 = (F_p + F_s) \quad \because (\text{both are collinear forces})$$

$$R_2 = 10000 + 16000 = 26000 \text{ N} \quad \text{--- (2)}$$

(i) Rivet No 2 & 4 are subjected to max shear force

(ii) mag of max shear force $R = 35402.2523 \text{ N}$

(iii) (also) $d = ?$

$$\left(\frac{R_1}{\text{Area}} \right) \leq \tau_{\text{per}}$$

$$\therefore \frac{35402.2523 \text{ N}}{\frac{\pi}{4} d^2} = 150 \text{ N/mm}^2$$

$$d = \text{dia of rivet} = 17.935 \text{ mm}$$

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Q1 (2)

(1)

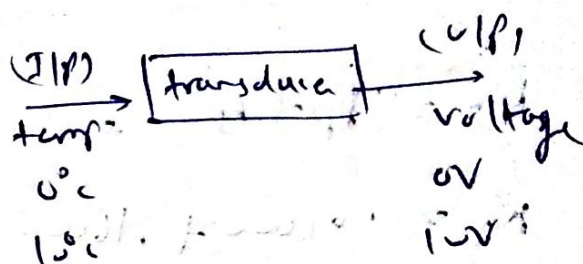
Accuracy of transducer

1) It is defined as the Ability to measure the true value of input.

It defines the closeness of measured value towards Actual/true value.

Sensitivity of transducer

2) It is the Ratio of change in output of transducer to the change in input of transducer.



then,

$$\text{sensitivity} = \frac{10 - 0}{10 - 0} = 1\text{V}/^\circ\text{C}$$

3) If the Resolution is very small then there is chance of high Accuracy.

(or)
If the Actual value is integral multiple of Resolution of transducer then, Accuracy is very high.

3) Sensitivity & Resolutions are not dependent on each other.

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3) As Non-linearity error decreases, Accuracy increases.

3) No Relation between sensitivity & Non-linearity error.

(ii)

Primary

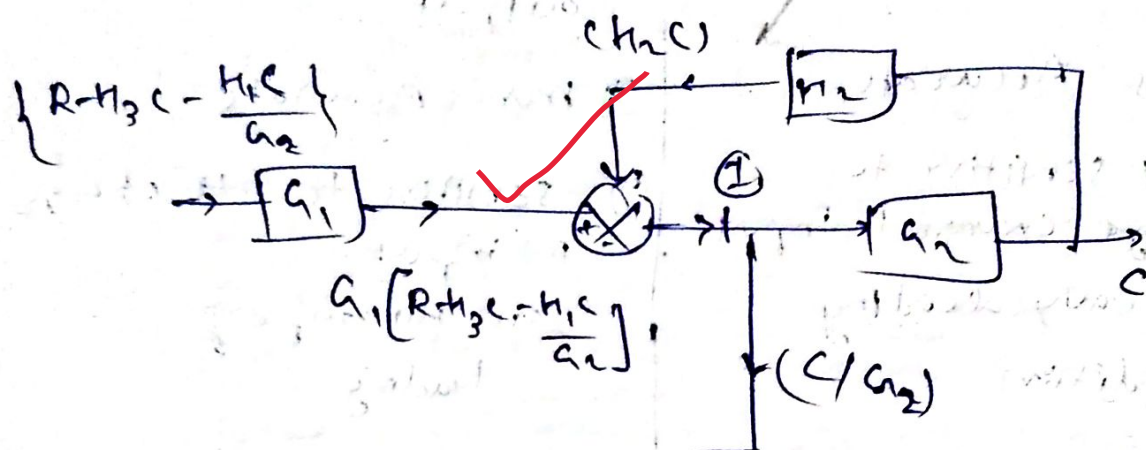
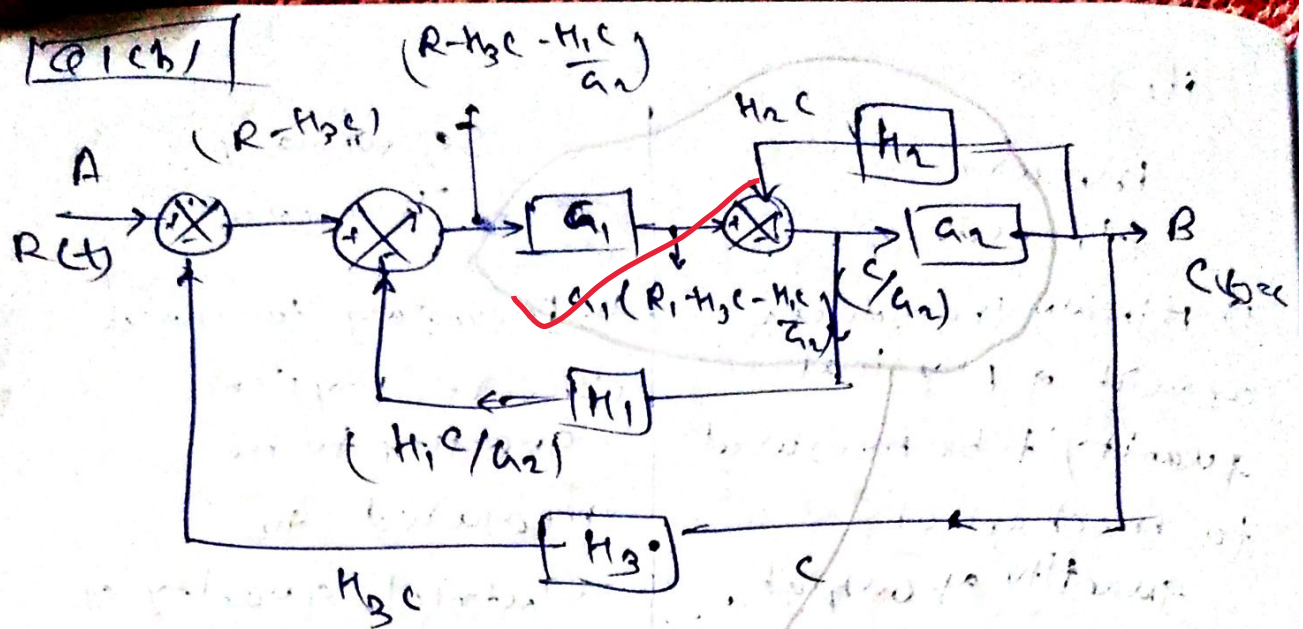
Transducer

- 1) Primary transducer convert a physical quantity to be measured to mechanical quantity as output.
- 2) less Accurate.
- 3) only sensitive to large change in input or heavy loading condition.
- 4) Programming can not be done easily.
- 5) mainly contain elastic members as component ex. Diaphragm.
- 6) ex. bellows, to measure press, Bourdon press. gauge.

Secondary

Transducer

- 1) Secondary transducer convert physical quantity to be measured to electrical quantity as output.
- 2) more Accurate.
- 3) sensitive to All change in input.
or All type of loading.
- 4) programming can be done easily.
- 5) mainly contains electronic Ckt as component.
- 6) ex. LVDT (linear variable diff. transducer).



$$\textcircled{I} = G_1 \left[R - H_3 C - \frac{H_1 C}{G_2} \right] - H_2 C$$

$\&$ this is equal to (C / G_2)

$$G_1 \left[R - H_3 C - \frac{H_1 C}{G_2} \right] - H_2 C = \frac{C}{G_2}$$

$$\left(R - H_3 C - \frac{H_1 C}{G_2} \right) = \frac{H_2 C}{G_1} + \frac{C}{G_1 G_2}$$

$$R - H_3 C - \frac{H_1 C}{G_2} = C \left[\frac{1}{G_1 G_2} + \frac{H_2}{G_1} \right]$$

$$R = C \left[H_3 + \frac{H_1}{G_2} + \frac{1}{G_1 G_2} + \frac{H_2}{G_1} \right]$$

R = Input signal

C = Output signal

(Closed loop) $G_o =$

$$\frac{C}{R} =$$

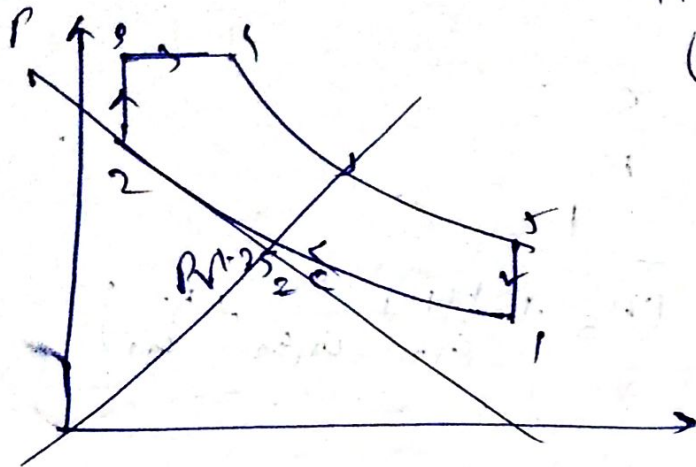
$$\frac{1}{(H_3 + \frac{H_1}{G_2} + \frac{1}{G_1 G_2} + \frac{H_2}{G_1})}$$



this is simplified form

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Q5 (a)



$$P_1 = 1 \text{ bar}, T_1 = 50^\circ\text{C} = 323 \text{ K}$$

$$(A/P = 25 \text{ H})$$

$$\gamma = 1.5$$

$$C_v = (0.71 + 21 \times 10^{-5} T) \frac{\text{kJ}}{\text{kg}}$$

$$C_v = 440 \text{ J/kg}$$

$$R = 287 \text{ J/kg}$$

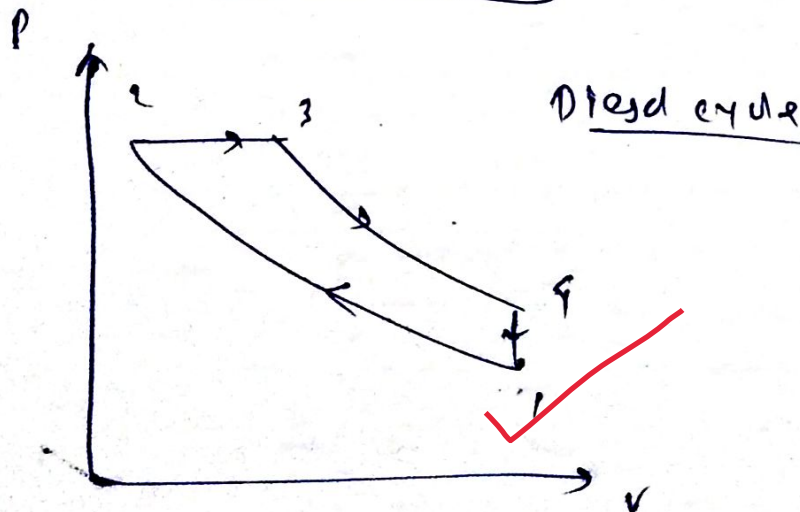
$$(P/P_1) = \dots$$

Now

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (2)^{\frac{1}{1.5}}$$

$$\left(\frac{T_2}{323}\right) = (15)^{\frac{1}{1.5}} = 2.58 \quad \therefore \boxed{T_2 = 833.363 \text{ K}}$$

$$\boxed{T_2 = 833.363 \text{ K}}$$



Diesel cycle

$$Q = (m \times C_v) \quad \text{if } n_{\text{comb}} = 1 \text{ unit}$$

$$Q = (m \times C_v) \times (T_3 - T_2)$$

$$Q = (m \times C_v) \int_{T_2}^{T_3} C_v dT$$

$$\therefore Q = m \dot{h} + 4400 \text{ W} \quad \text{--- (1)}$$

Now,

$$Q = (m + m \dot{h}) \times \int_{T_1}^{T_3} (0.71 + 10^{-5} \times T) \, dT$$

$$= (m + m \dot{h}) \times \left[0.71 \times (T_3 - T_1) + \frac{1}{2} \times 10^{-5} \times (T_3^2 - T_1^2) \right] \quad \text{--- (2)}$$

$\therefore$ From (1) & (2)

$$(m \dot{h} + 4400) \text{ W} = (m + m \dot{h}) \times$$

$$\left[0.71 \times (T_3 - T_1) + \frac{1}{2} \times 10^{-5} \times (T_3^2 - T_1^2) \right]$$

$$4400 = (2541) \times \left[0.71 \times (T_3 - 833.3(34)) + \frac{1}{2} \times 10^{-5} \times (T_3^2 - 833.3(34)^2) \right]$$

$$1692.307692 = 0.71 T_3 - 591.688 + 1.05 \times 10^{-5} T_3^2 - 0.0975$$

$$0 = 1.05 \times 10^{-5} T_3^2 + 0.71 T_3 - 2284.002 \quad 2356.912$$

$$T_3 = 2379.604 \text{ K}$$

$$T_3 = 2439.5 \text{ K}$$

calculation
error

$$P = \frac{V_3}{V_2} = \left(\frac{T_3}{T_2} \right) = \frac{2439.51}{833.3634} = \underline{2.927}$$

$$(P-1) = \eta_p (r-1)$$

$$(2.927-1) = \eta_p (15-1)$$

$$\eta_p = 12.264$$

procedure is correct

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$\therefore$ No. of strokes at which combustion complete is 15.264

Q5ch)

HAUT.

$V_{w1} = 1 \text{ cm}^3$ at 1 atm, 288K

$D_R = 120 \text{ m}$, $N_R = 402 \text{ rpm}$

T_m = torque produced at max power output

$$T_m = (C_T)_{\max} (T_{\max})$$

$$(C_T)_{\max} = \left(\frac{0.593}{\lambda} \right) \times (T_{\max})$$

$$(C_T)_{\max} = \frac{0.593}{\lambda}$$

$$\lambda = \frac{R_w}{V_{w1}}$$

$$\lambda = 60 \times \left(\frac{2\pi \times 40}{60} \right)$$

$$\therefore (C_T)_{\max} = \left(\frac{0.593}{25.1327} \right)$$

$$\lambda = 25.1327$$

$$T_{max} = F_{max} \times (R)_{rem}$$

$$= \frac{1}{2} \rho \times v_{air}$$

$$= \left(\frac{1}{2} \times \rho \times A \times v_{air}^2 \right) \times R_{rem}$$

$$= \frac{1}{2} \times \left(\frac{1.225 \times 10^3}{2.22 \times 2.22} \right) \times \frac{\pi}{4} \times 1.0^2 \times 10^2 \times 60$$

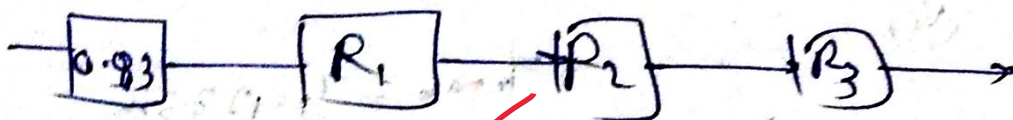
$$= 41.592579 \times 10^6 \text{ Nm}$$

$$T_m = \frac{0.593}{25.1327} \times T_{max}$$

$$T_m = 981311.63 \text{ Nm}$$

Q5(c)

$$R_{overall} = R_o$$



$$R_o = 0.83 \times R_1 \times R_2 \times R_3$$

$$\text{Now } R_1 = 1 - (1 - 0.83)(1 - 0.83)(1 - 0.79)$$

$$R_1 = 0.989177$$

$$R_2 = 1 - (1 - 0.83)(1 - 0.85)(1 - 0.79)$$

$$R_2 = 0.993115$$

$$R_3 = 1 - (1 - 0.99)(1 - 0.87)$$

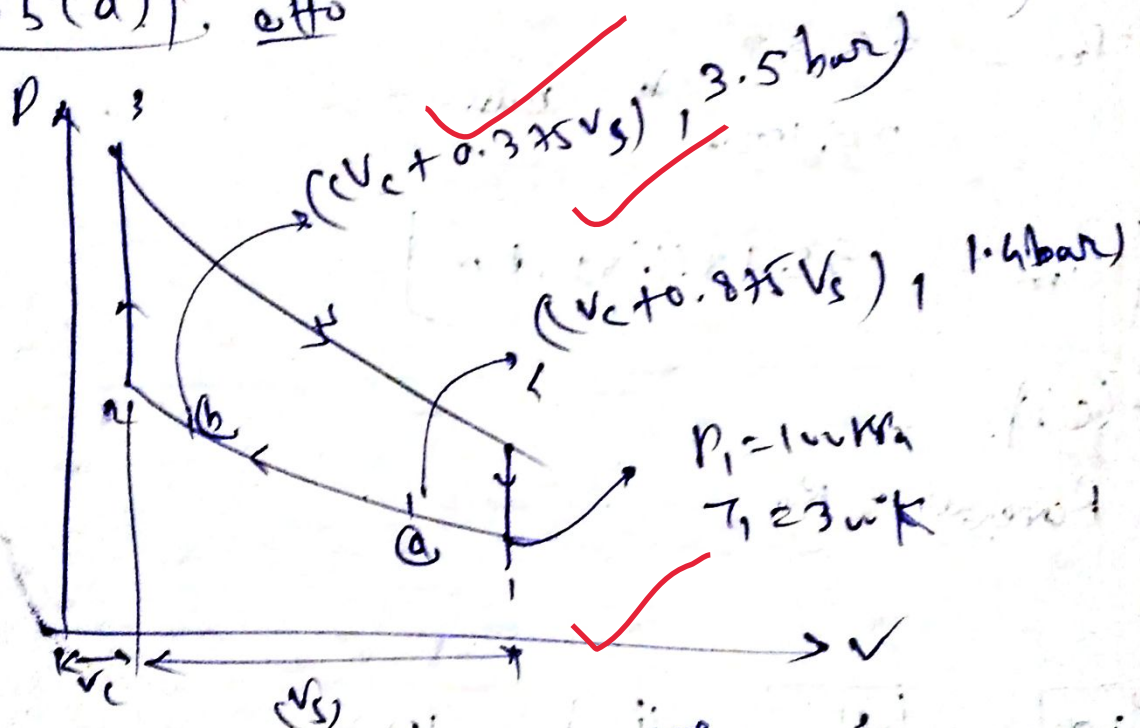
$$R_3 = 0.9909$$

from a, b, c, d

$$R_0 = 0.83 \times 0.989647 \times 0.993115 \times 0.9909$$

$$R_0 = 0.8272 \quad \text{Overall Reliability}$$

Q5(d). Otto



$$P_1 = 100 \text{ kPa}$$

$$T_1 = 300 \text{ K}$$

$$T_{\text{max}} = T_3 = 1273 \text{ K}$$

compression is isentropic i.e. $Pv^{1.4} = \text{const}$

$$P_a(v_a)^{1.4} = P_b(v_b)^{1.4}$$

$$(1.4 \text{ bar}) \times (v_c + 0.875 v_s)^{1.4}$$

$$= 3.5 \text{ bar} \times (v_c + 0.375 v_s)^{1.4}$$

$$C = \frac{V_c}{V_s} \quad (\lambda = 1 + \frac{1}{\epsilon})$$

$$\left(\frac{V_c + 0.875 V_s}{V_c + 0.375 V_s} \right)^{1.4} = \frac{3.5}{1.4}$$

$$= 2.5$$

$$\frac{\frac{V_c}{V_s} + 0.875}{\frac{V_c}{V_s} + 0.375} = (2.5)^{\frac{1}{1.4}} = 1.9241$$

$$\frac{C + 0.875}{C + 0.375} = 1.9241$$

$$C + 0.875 = 1.9241(C + 0.375)$$

$$0.15343 = 0.5241C$$

$$\boxed{C = 0.1111} \therefore \lambda = 1 + \frac{1}{\epsilon} = \underline{\underline{7.023}}$$

(i) Compression Ratio $= \lambda = \underline{\underline{7.023}}$

(ii) $(\eta_{\text{isent}}) = 1 - \frac{1}{\lambda^{\gamma-1}} = 1 - \frac{1}{7.023^{0.4}}$

$$= \underline{\underline{54.145\%}}$$

(iii) $Q_{\text{supplied}} = m C_v (\tau_3 - \tau_2)$

$$= 1 \times 0.717 \times (1273 - \tau_2)$$

$$\frac{T_2}{T_1} = (r)^{\gamma-1} = (7.023)^{1.4-1} = 2.18076$$

$$T_2 = 654.229 \text{ K}$$

$$\begin{aligned} Q_{\text{supplied}} &= 1 \times 0.711 \text{ kJ/kg} (1273 - 654.229) \\ &= 443.658 \text{ kJ/kg} \end{aligned}$$

(iii) $W_{\text{net}} = h \times Q_{\text{supplied}}$

$$= 0.54144 \times 443.658$$

$$= 240.24 \text{ kJ/kg}$$

Q5 (e)

For fuel cell, $h_{\text{max}} = ?$

In fuel cell, ~~the~~ chemical energy stored in fuel gets converted in electrical energy

under steady operation:

$$W = Q - \Delta H$$

For max work, process must be reversible

$$Q_{\text{rev}} = T \Delta S$$

$$W = T \Delta S - \Delta H$$

$$W = -(\Delta H - T \Delta S)$$

$$G = H - TS \quad (\text{Gibbs free energy})$$

$$\begin{aligned}\therefore \Delta G &= \Delta H - \Delta(TS) \\ &= \Delta H - (T\Delta S + S\Delta T) \\ \Delta G &= \Delta H - T\Delta S \quad \text{--- (2) } (\because \Delta T=0)\end{aligned}$$

from (1) & (2)

$$W = -(\Delta G) = W_{\max}$$

$$\eta = \frac{\text{output}}{\text{input}} = \frac{W}{-\Delta H} = \frac{-\Delta G}{-\Delta H} = \frac{\Delta G}{\Delta H}$$

is proved

Q7 (b)

$K=1$ (single cylinder), 4 stroke

$$A_d = 300 \text{ mm}^2, \quad d_d = 40 \text{ mm}$$

$$S_p = 1 \text{ bar/mm} \quad \therefore (h_d) = \frac{A_d}{d_d} = \frac{300 \text{ mm}^2}{40 \text{ mm}}$$

$$h_d = 7.5 \text{ mm}$$

$$P = S_p \times h_d$$

$$= 1 \text{ bar/mm} \times 7.5 \text{ mm}$$

$$= 7.5 \text{ bar} = P_{\text{ref}}$$

$$W = 370 \text{ N}$$

$$S = 50 \text{ mm}$$

$$(W-S) = 370 - 50 \\ = 320 \text{ N}$$

$$(d)_{\text{drum}} = 0.1 \text{ m}, \quad m_f = 2.8 \text{ kg/hr}$$

$$(C_v)_f = 41.8 \text{ MJ/kg}$$

$$d = 0.16 \text{ m}$$

$$L = 0.2 \text{ m}$$

$$\text{(i) } P_{\text{ref}} = 7.5 \text{ bar}$$

$$(i) BP = \frac{2\pi NT}{60} \rightarrow T = (W-S) \times \text{radius}$$

$$T = (370-50) \times 0.6 = \underline{192 \text{ Nm}}$$

$$BP = \frac{2\pi \times 400 \times 192}{60} = \underline{8.0424 \text{ kW}}$$

$$(b_{meq}) = \frac{BP}{(\dot{V}_{swept})}$$

$$(\dot{V}_{swept}) = \frac{\pi d^2 l}{4} \times \frac{N}{60 \times 2} \times (K)$$

$$= \frac{\pi \times 0.16^2 \times 0.2 \times 400}{4 \times 120} \times (1)$$

$$= 0.0134041 \text{ m}^3/\text{s}$$

$$(b_{meq}) = \frac{8.0424 \times 10^3}{0.0134041} = \underline{5.999 \text{ bar}}$$

$$(iii) \underline{bsfc} = \frac{m_f \times 3600}{(BP)}$$

$$= \frac{2.2 \text{ kg/hr}}{8.0424} = \underline{0.34815 \frac{\text{kg}}{\text{kWh}}}$$

$$(iv) (h_{BTH}) = \frac{(BP)}{m_f \times CV} = \frac{8.0424 \times 10^3}{\left(\frac{2.2}{3600}\right) \times 41.8 \times 10^6} = \underline{24.73\%}$$

$$\begin{aligned}
 V(I_p) &= P_{\text{mer}} \times (V_{\text{sweep}}) \\
 &= 7.5 \times 10^2 \times 0.0134041 \\
 &= \underline{10.053 \text{ kW}} \quad \checkmark
 \end{aligned}$$

$$\begin{aligned}
 C_{\text{hwh}} &= \frac{10.053 \text{ kW}}{\frac{2.8}{3 \text{ hr}} \times 41.8 \times 10^3} = \underline{30.9217\%}
 \end{aligned}$$

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Q7(c) 1 family = 5 Adult
2 low (lamp) (the density)

(vdm) ~~gasifier~~ = ? , No of cur. ?
Plant

① For cooking : $Q_{\text{cooking}} = 2$

$$q_c = 0.227 \text{ m}^3/\text{person/day}$$

$$\begin{aligned}
 5 \times q_c &= 5 \times 0.227 \text{ m}^3/\text{day} \\
 &= \underline{1.135 \text{ m}^3/\text{day}} \quad \text{--- ①}
 \end{aligned}$$

② For lamp : $Q_{\text{lamp}} = ?$

$$q_L = 0.126 \text{ m}^3/\text{hr/day}$$

$$\begin{aligned}
 2 \times q_L &= (2 \times 0.126 \times 3) \text{ m}^3/\text{day} \\
 &= \underline{0.756 \text{ m}^3/\text{day}}
 \end{aligned}$$

$$\begin{aligned}
 \therefore \text{total daily requirement of gas} &= 1.135 + 0.756 \\
 &= \underline{1.891 \text{ m}^3/\text{day}}
 \end{aligned}$$

cow dung by 1 cow = 10 kg / day

$$\text{collectable cow dung} = 0.2 \times 10 \\ = 2 \text{ kg / day}$$

$$(\text{dry matter}) = (0.18 \times 7) / \text{day} \\ = 1.26 \text{ kg / day}$$

$$(\text{gas yield / day}) = 0.34 \text{ m}^3 / \text{dry matter} \times 1.26 \\ = 0.4284 \text{ m}^3 / \text{day}$$

$$\therefore \text{per day per cow gas yield} = 0.4284 \text{ m}^3$$

$$\text{but per day requirement} = 1.891 \text{ m}^3$$

$$\therefore \text{No of cows} = \frac{1.891}{0.4284} = 4.41 \approx 5$$

$$\therefore \boxed{\text{No of cows} = 5}$$

$$\therefore \text{total collectable cow dung / day}$$

$$= 5 \times 7 = 35 \text{ kg}$$

$$\therefore \text{total slurry (kg)} = 35 + 35 \\ = 70 \text{ kg}$$

$$(\text{vol}^m \text{ slurry}) = \frac{70 \text{ kg}}{1090 \text{ kg/m}^3} = 0.0642 \text{ m}^3 / \text{day}$$

$$(\text{total vol}^m) = 5 \text{ days} \times 0.0642 \\ = 3.21100 \text{ m}^3$$

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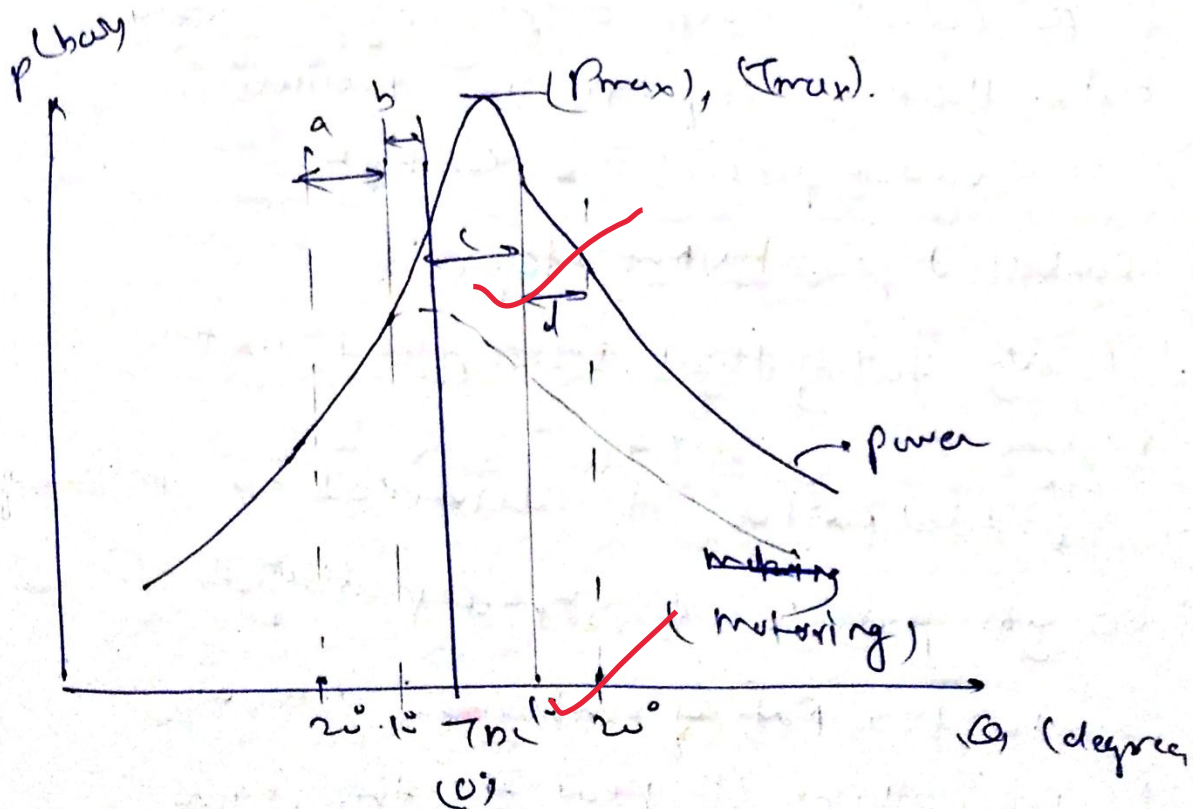
$$(Vol^m) \text{ plant} = \frac{3.2110}{0.9} = \underline{\underline{3.56778 m^3}}$$

Q7(a)

combustion in CI engine

- In CI engine, combustion is heterogeneous
- there are generally 4 stages of combustion

- (1) Ignition delay (a)
- (2) uncontrolled combustion (b)
- (3) controlled combustion (c)
- (4) After burning combustion (d)



(1) Ignition delay:

- In this stage, compression is going on,
- For uniform distribution of fuel particles, vaporization of them, & mixing ~~of~~ for chemical action some time is required so for that

Fuel is supplied (20°) generally before top dead centre.

Region (a) is the time required for all these operations & after combustion starts.

(2) Uncontrolled Combustion

- Nearly 30% Heat is supplied in this
- As oxygen molecules are ~~readily~~ readily available with elevated temp. fuel particles start burning & form high velocity flame fronts at various points inside the engine cylinder
- As rate of flame displacement is very high there is sharp rise in pressure.
- ∴ It is called uncontrolled combustion

(3) Controlled combustion stage

- Nearly 70% of Heat is supplied in this region
- As fuel particle is surrounded by mixture of fine gas particles & oxygen particles due to this rate of combustion decreases & pressure attains its peak in this region & after that due to expansion stroke, pressure decreases.

(4) After combustion - Not all time this region exists in every cycle.

- In some cycle only this combustion happens.

- due to some extra particle of fuel, those who don't get sufficient oxygen to burn, burn in this stage
- this combustion is not at all favorable, it contributes to shock wave formation, noise, vibration of engine

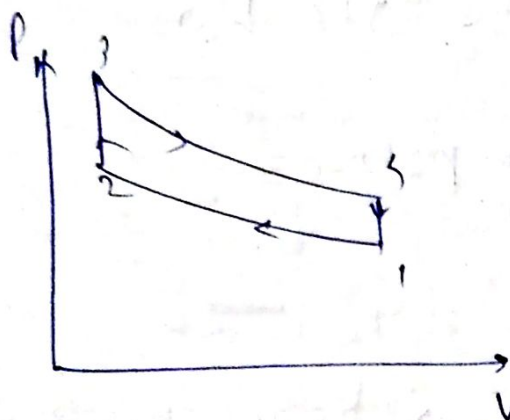
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Q6(a) Otto cycle
 $\lambda = 6$, $C_{8H_{18}}$, $C_v = 4500 \text{ J/kg}$

A/F perfect = 15:1

$C_v = 0.718 \text{ kJ/kgK}$, $P_1 = 1 \text{ bar}$, $T_1 = 330 \text{ K}$

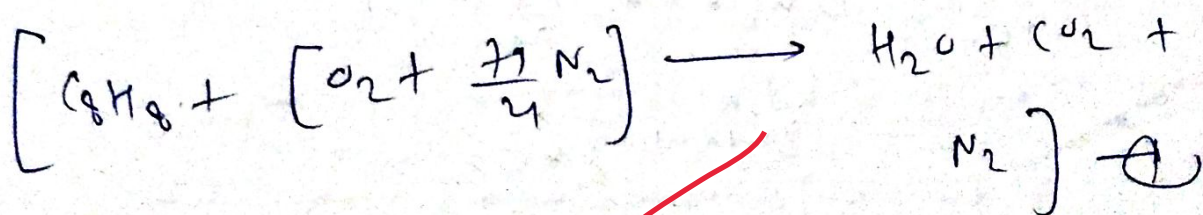
$n = 1.32$, $(Pv^n = C) \rightarrow$ compression



(1) without considering
 mole phenomenon.

$$\frac{T_2}{T_1} = (\lambda)^{n-1} = (6)^{1.32-1} = 1.774$$

$$T_2 = 585.42 \text{ K}$$



$$Q_{supplied} = m_f \times CV = (m + m_f) \times CV \times (T_3 - T_2)$$

$$CV = \left(\frac{m_a}{m_f} + 1 \right) \times CV \times (T_3 - T_2)$$

$$44000 = (15+1) \times 0.718 \times (T_3 - 585.44)$$

$$\boxed{T_3 = 4415.50 \text{ K}} = T_{\text{max}} \quad \text{--- (2)}$$

Now,

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{T_2}{T_1}\right)^{\gamma} = (6)^{1.32} = 10.6453$$

$$\boxed{P_2 = 10.6453 \text{ bar}}$$

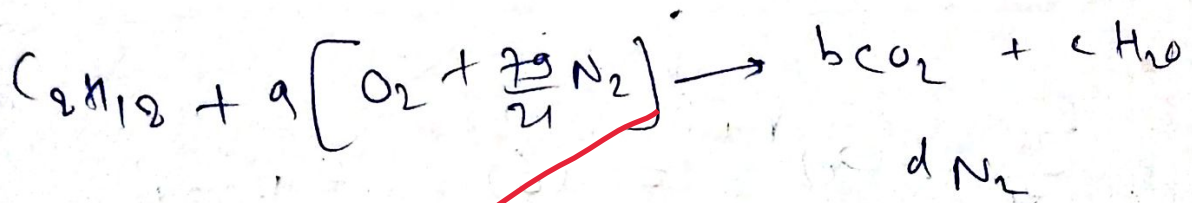
$$\frac{P_3}{P_2} = \frac{T_3}{T_2} \rightarrow P_3 = P_2 \times \frac{T_3}{T_2}$$

$$P_3 = 10.6453 \times \frac{4415.50}{585.42}$$

$$\boxed{P_3 = 80.29162 \text{ bar}}$$

(ii) with considering molecular phenomenon

from eqn (1)



$$A/F = \frac{15}{1}$$

$$15 = \frac{a \times (32 + \frac{79}{21} \times 28)}{2 \times 12 + 18 \times 1}$$

$$15 = a \times 1.204679$$

$$\boxed{a = 12.4514}$$

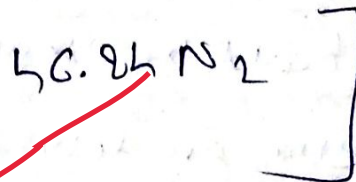
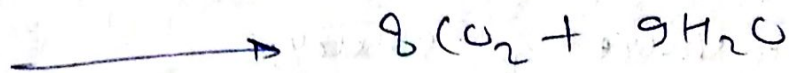
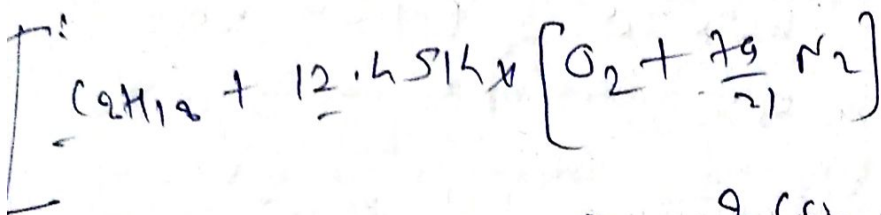
Comparing

$$\frac{C}{\text{Carbon}} : - \quad 18 = 6$$

$$H : - \quad 18 = 2 \times C \quad \therefore \boxed{C = 9}$$

$$N : \quad 2 \times \frac{79}{21} \times (9) = 2 \times 9$$

$$\frac{79}{21} \times 12.4514 = 46.84$$



n_1 = mole before combustion

$$= 1 + 12.4514 + 12.4514 \times \frac{79}{21}$$

$$= \cancel{12.4514} \quad 60.2923$$

n_2 = mole After combustion

$$= 8 + 9 + 46.84 = 63.84$$

$\therefore$ molecular expansion took place

$$\therefore P_{\text{max}} = 80.29162 \times \frac{63.84}{60.2923} = 295.0111 \text{ bar}$$

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~~Q 6(a)~~ | Q 6(b)

* Factors Affecting the performance of biogas digester:-

1) Temperature:- temp of ^{inside} digester is imp Parameter, it should be maintained (20° to 35° C)

For every 5° C rise, gas production rate double, but below 20° C, rate decreases & same above 55° C.

2) pH value of slurry:-

- It should be maintained within 6.5 to 7.5 pH
- Bacteria are very sensitive to Acidic environment
- growth affected largely for extreme basic & Acidic environment

3) Feed Rate:- It should be optimum

- when Feed Rate increases, then undigested slurry come out of outlet / waste pipe
- when Feed Rate is low, then slurry get accumulated inside the dom & affect gas formation

4) Seeding of biomass:-

- by Adding Active slurry (contains inbuilt bacteria to produce gas), Rate of gas formation increases.

5) Retention time :-

- it depends on what materials we are using as input to digester ✓
- it varies material to material
- For example it is 50 days ✓

6) Water concentration inside Slurry

- water is necessary for
 (i) movement of bacteria
 (ii) well mixing of slurry.
- optimum water concentration should be maintained.

7) (C to N) Ratio

- C = carbon, it is used to gain energy, & energy supply to the bacteria & it works toward, gasification.
- N = Nitrogen, it is cell building structure. It determines growth of bacteria inside.

$$(C:N) \approx 30:1$$

12

refer solution

[Q 6(C)]

(1).

(1) vibration monitoring technique:-

- It is one of the widely used condition based maintenance / monitoring method
- It senses vibration signal of machine component / machine as whole
- it measures, Amplitude of vibration, Frequency of vibration, acceleration & velocity
- the probe is attached at the bearing, or where there is more chance of getting machine vibrated
- with the help of sensors, the wave form is generated at display of machine & required action of maintenance is taken

(2). wear & debris monitoring:-

- there are many different mechanism of wear such as, Abrasion, Adhesion, erosion, chemical corrosion wear etc
- ultimately All these produce micro size particles of different size from $1 \mu m$ to $1000 \mu m$ & these particles get settled down in the oil bath.

- with the help of size, shape, composition & amount of wear debris & Rate of deposition of wear debris, action of maintenance is taken.

- As mentioned earlier, (size, shape, composition) of wear particles are studied in wear debris monitoring.

(3) Thermography

- IR Rays (Infrared Rays) are used in this CBM. (Condition based monitoring techniques)

- ~~There is~~ Contact between machine component & sensing equipment of IR is Not Necessary

- to this method is widely used in high temp. Component Analysis such as boiler, furnace etc

- IR Rays are incident on the part of Component to be monitored, & we get some distinct pattern as per condition of part

- with the help of that pattern, analysis is done.

(4) Visual inspection:

- one of the cheap method / cheapest method.

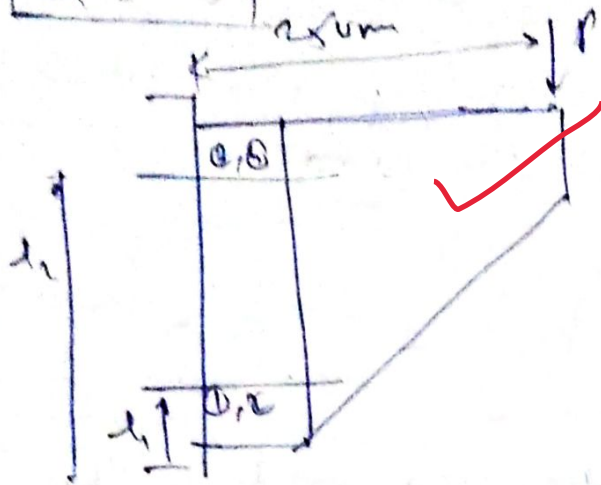
- surface crack, surface defects in casting, welding

(or) any other forming operation are easily detected.

Q6(c)

(i)

Q3(a)



4 bolts

$$l_1 = 75 \text{ mm}, \approx l_2$$

$$l_3 = l_4 = 375 \text{ mm}$$

$$P = 5000 \text{ N}$$

$$e = 25 \text{ mm}$$

$$P_0 = 51$$

(F_p) = primary shear force

$$(F_p) = \frac{5000}{4} = 1250 \text{ N} \quad \text{--- (1)}$$

$$(F_{\text{bending}}) = \frac{P \times e \times l_i}{\sum l_i^2}$$

$$(F_b)_{1/2} = \frac{(5000 \times 25) \times (75)}{2 \times (75^2 + 375^2)} = 320.51 \text{ N}$$

Resultant force =

$$(C_h) = \left(\frac{F_b}{A} \right) = \frac{320.51 \text{ N}}{\frac{\pi}{4} (d_c)^2} = \frac{408.09959}{(d_c)^2}$$

$$\tau = \frac{1250 \text{ N}}{\frac{\pi}{4} (d_c)^2} = \frac{1591.559 \text{ N/mm}^2}{(d_c)^2}$$

maxm principle stress then

$$\sigma_{max} = \frac{\sigma_h}{2} + \sqrt{\left(\frac{\sigma_h}{2}\right)^2 + \tau^2} = \text{permissible}$$

$$= \frac{\left(\frac{408.08559}{d_c^2}\right)}{2} + \sqrt{\left[\frac{\left(\frac{408.08559}{d_c^2}\right)}{2}\right]^2 + \left(\frac{1591.539}{d_c^2}\right)^2}$$

$$= \frac{204.04279}{d_c^2} + \frac{1604.575}{(d_c)^2}$$

$$= \frac{1808.620}{d_c^2} = \left(380 \times \frac{1}{5}\right)$$

$$d_c = 4.879 \text{ mm}$$

$$d = \frac{d_c}{0.84} = 5.8074 = \underline{\underline{6 \text{ mm}}}$$

$\therefore$ major dia of bolt = 6 mm

Now,

$$(F_h)_{3/4} = \frac{(5000 \times 250) \times 375}{2(375^2 + 75^2)} = 1602.514 \text{ N}$$

$$(\sigma_h) = \frac{(F_h)}{\frac{\pi}{4} d_c^2} = \frac{2040.4479}{(d_c)^2} \quad \text{--- A}$$

$$\tau = \frac{1200}{\frac{\pi}{4} d_c^2} = \frac{1591.539}{(d_c)^2} \quad \text{--- B}$$

by using max principle they

$$\sigma_{max} = \sigma_{principle} = (\sigma_{xx}/\sigma_{yy})$$

$$\sigma_{max} = \left(\frac{\sigma_b}{2}\right) + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + (\tau)^2}$$

$$= \left(\frac{2040.4479}{d_c^2 \times 2}\right) + \sqrt{\left(\frac{2040.4479}{d_c^2 \times 2}\right)^2 + \left(\frac{1596.579}{d_c^2}\right)^2}$$

$$= \frac{1020.224}{(d_c)^2} + \frac{1890.472}{(d_c)^2}$$

$$= \frac{2910.691}{(d_c)^2}$$

$$\frac{2910.691}{(d_c)^2} = \frac{300}{5}$$

$$\therefore d_c = 6.182$$

$$d = \frac{d_c}{0.8} = \underline{\underline{7.735}}$$

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(M10) bolt is used for this

Q306) $m = 1 \text{ kg}$, $S = 2 \text{ N/m}$.

$$C = 2 \text{ N/m}$$

$$x_0 = \frac{r^2 x_i}{\sqrt{(1-r^2)^2 + (2\xi r)^2}}$$

$$1 \quad (r = \omega/\omega_n)$$

$$\omega = 1.25, \quad \omega_n = \sqrt{\frac{2}{1}} = 1.414$$

$$|r| = 0.8838$$

$$\gamma = \frac{c}{c_0} = \frac{c}{2 \mu \omega n} = \frac{2}{2 \times 1 \times 1.514} = 0.707$$

$$X_0 = (0.8938)^2 \times (1)$$

$$\sqrt{(1 - 0.8938)^2 + (2 \times 0.707 \times 0.8938)^2}$$

$$X_0 = 0.6151 \text{ (X)}$$

04

$$\therefore X_0(t) = 10 \times 0.6151 \times \sin(1.25t)$$

$$X_0(t) = 6.151 \sin(1.25t)$$

refer solution for this Q

Q3(c)

$$(R_A + R_E) = 5000 \text{ N}$$

$$R_A = \frac{3\omega}{(3\omega + 4\omega)} \times 5000 = \frac{3}{7} \times 5000$$

$$R_A = 2142.857 \text{ N}$$

$$R_E = 2857.1429 \text{ N}$$

Now,

$$C_{ut} = 50 \text{ N/mm}^2$$

$$S_e^* = 0.5 C_{ut} = 0.5 \times 50 = 25 \text{ N/mm}^2$$

$$S_e = K_A K_b K_c K_d \times S_e^*$$

$$\text{Now, } K_d = \frac{1}{K_f} \quad \& \quad q = \frac{K_b + 1}{K_c - 1}$$

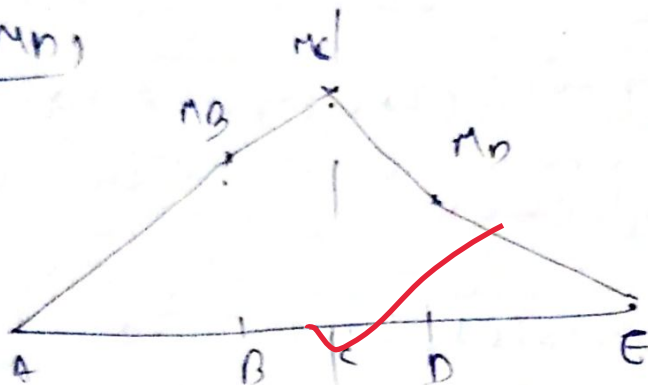
$$0.78 = \frac{K_f - 1}{1.72 - 1} \rightarrow K_f = 1.5616$$

$$S_e = \cancel{0.79} \times$$

$$S_e = 0.79 \times 0.95 \times 0.947 \times \left(\frac{1}{1.5/11} \right) \times 250$$

$$S_e = 91.429 \text{ N/mm}^2$$

(BMM)



$$(M_B) = R_A \times 3w = 2142.857 \times 3w$$

$$= 642857.14 \text{ y Nmm}$$

$$M_C = 2142.857 \times 4w = 857142.857 \text{ Nmm}$$

$$M_D = R_E \times 2w = 2142.857 \times 2w$$

$$= 571428.57 \text{ Nmm}$$

Now,

$$(\sigma_B) = \left(\frac{M_B}{I} \right) = \frac{32M}{\pi d^3} = \frac{32 \times 642857.14 \text{ y}}{\pi \times (30)^3}$$

$$\sigma_B = 242.5248 \text{ N/mm}^2$$

$$\sigma_C = \frac{32M}{\pi d^3} = \frac{32 \times 857142.857}{\pi \times (45)^3}$$

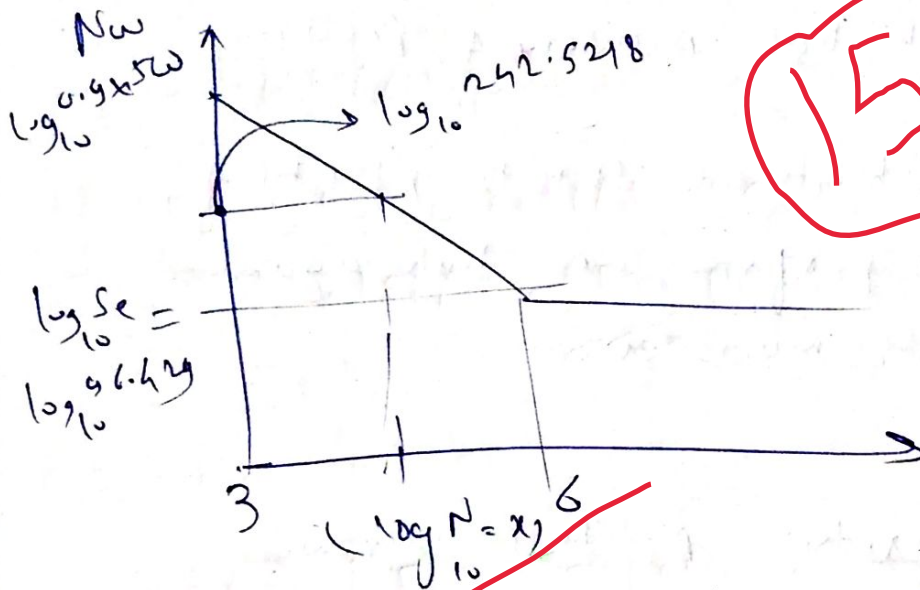
$$= 95.2110 \text{ N/mm}^2$$

$$\sigma_D = \frac{32M}{\pi d^3} = \frac{32 \times 571428.57}{\pi \times (35)^3}$$

$$= 138.7556 \text{ N/mm}^2$$

by comparing, $\sigma_B, \sigma_C, \sigma_D$:-

$$(\sigma_B) = \sigma_{\max} = 242.5218 \text{ N/mm}^2$$



$$\frac{\log 0.9 \times 5w - \log 96.44}{6 - 3} = \frac{\log 242.5218 - \log 96.44}{6 - \log N}$$

$$N = 15990.26 \text{ cycles} \rightarrow \text{this is life of shaft}$$

[Q3cd)]

(i) Reach :- It is ^{maximum} distance achieved by manipulator in ~~x, y, z~~ direction.

Reach is another name for work envelope.

- It is the space within which manipulator can work.

2) precision :- It is the ability of Robot manipulator to go to the position Repetably in every command.

- the position it go may not be the commanded position.

∴ Accuracy & precision are different
we want both Accuracy & precision.

3) Repeatability :- It is the Ability of Robot to perform same task again and again with much error.

5) Dexterity :- As DOF increases Robot become dextrous.

- It is the quality of Robot manipulator to give No of degrees of freedom to the manipulator as whole.

- total 6 degrees of freedom are there

ok