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ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-8: Machine Design + Mechatronics & Robotics + IC Engine

Name : .....

Roll No : M E 1 9 M T D L A 0 0 2

Test Centres					Student's Signature
Delhi ☑	Bhopal ☐	Noida ☐	Jaipur ☐	Indore ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	36
Q.2	—
Q.3	40
Q.4	—
Section-B	✓
Q.5	30
Q.6	—
Q.7	39
Q.8	49
Total Marks Obtained	187

Signature of Evaluator SM

Cross Checked by Gaurav

Section A : Machine Design + Mechatronics & Robotics

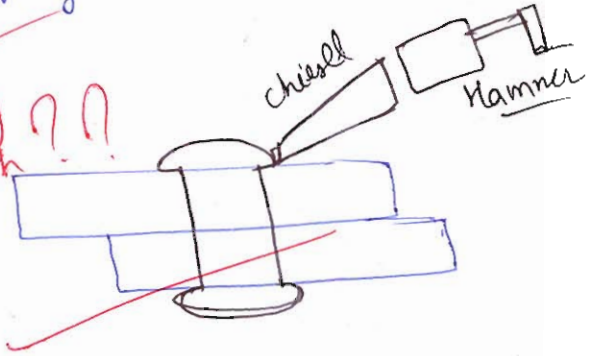
(a) What is caulking and fullering in riveted joint? Briefly explain with the help of diagram. **[12 marks]**

→ Both are the used for maintaining leak proof joint in the riveted (rivet).

⇒ Fullering :-

In this process first rivet is placed at a specific place than with the help of chiesel and hammer pressure is apply near to the head of the rivet so that rivet fit properly with the help of hammering action.

Diagram caulking ?? & fullering both



→ These are place at a specific angle near about 30 to 45°.

Caulking :-

This is also the used for making leak proof joint with the help of hammer but the angle of inclination of the chiesel is different than the fullering.

at end of the tool it is conical but in fullering it is flat

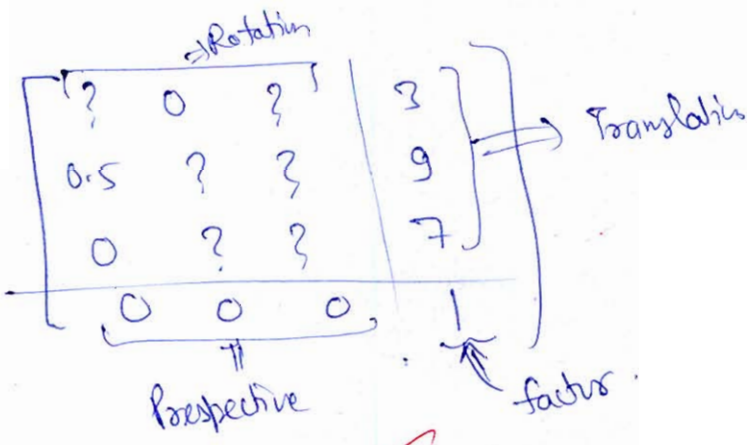
05

Do no write this m

Q.1 (b) For the following frame, find the values of the missing elements and complete the matrix representation of the frame.

$$F = \begin{bmatrix} ? & 0 & ? & 3 \\ 0.5 & ? & ? & 9 \\ 0 & ? & ? & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[12 marks]



So

$$\begin{bmatrix} \hat{i}\cdot\hat{i} & \hat{i}\cdot\hat{j} & \hat{i}\cdot\hat{k} \\ \hat{j}\cdot\hat{i} & \hat{j}\cdot\hat{j} & \hat{j}\cdot\hat{k} \\ \hat{k}\cdot\hat{i} & \hat{k}\cdot\hat{j} & \hat{k}\cdot\hat{k} \end{bmatrix}$$

$\hat{k}\cdot\hat{k} = kk\cos 0^\circ = kk$

$\hat{i}\hat{j} + \hat{j}\hat{j} + \hat{i}\hat{k} = 0$

$\hat{i}\hat{i} = -\hat{i}\hat{k}$

$\hat{i}\hat{i} + 0.5 + 0 = 1$

$\hat{i}\hat{i} = 0.5$

So $\hat{i}\hat{k} = -0.5$

$\hat{j}\hat{j} + \hat{j}\hat{j} + \hat{k}\hat{j} = 0$

$0.5 + \hat{k}\hat{j} = 0 \Rightarrow \hat{k}\hat{j} = -0.5$

& $\hat{i}\hat{j} + \hat{j}\hat{j} + \hat{j}\hat{k} = 1$

$0.5 + \hat{j}\hat{j} + \hat{j}\hat{k} = 1$

$\hat{j}\hat{j} + \hat{j}\hat{k} = 0.5$

$\Rightarrow$

$\hat{i}\hat{j} + \hat{k}\hat{j} + \hat{k}\hat{k} = 0$

$\hat{k}\hat{j} + \hat{k}\hat{k} = 0 \Rightarrow \hat{k}\hat{k} = -\hat{k}\hat{j}$

$\hat{j}\hat{i} + \hat{j}\hat{k} + \hat{k}\hat{k} = 0$

$-0.5 + \hat{j}\hat{k} + \hat{k}\hat{k} = 1$

So $\hat{k}\hat{k} = -\hat{j}\hat{j} = -\hat{k}\hat{k}$

$\hat{j}\hat{j} = 0.5 - \hat{j}\hat{k}$

$\Rightarrow -0.5 + 0.5 - \hat{j}\hat{j} - \hat{j}\hat{j} = 1$

$\hat{j}\hat{j} = 0.5$

$$\left[\begin{array}{ccc|c} 0.5 & 0 & 0.5 & 3 \\ 0.5 & -0.5 & 1 & 9 \\ 0 & 0.5 & 0.5 & 7 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

01

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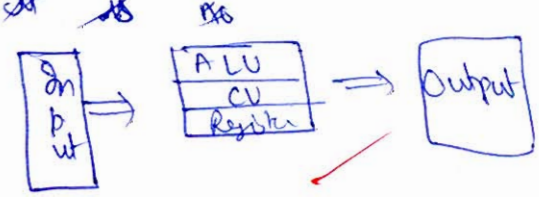
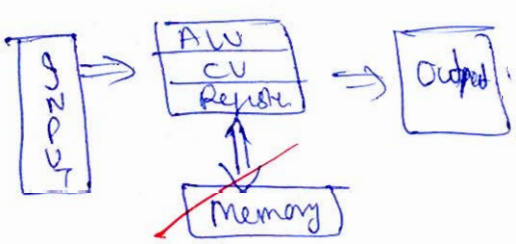
Q.1 (c) Enumerate the differences between micro-processor and micro-controller.

[12 marks]

	Micro processor	Micro Controller
1:	for the general purpose used.	1 for the specific purpose used.
2:	In this the memory is not the part.	2:- Memory is the part of Micro Controller
3:	8085, 8086 and many more example.	3: Octacore, tetracore are platinum are example
4:	It work at a very high speed.	4: Compare to less speed.
5:	Micro processare are mounted on the Inggrated circuit (IC) chip	5: there are separate kits.
6:	Micro processor Contain ALU, CU & Register.	6: It Contain ALU, CU Register and external memory also.
7:	Micro procesor are used in robot, computer,	It is not used in the robot.
8:		

Q07 (More points required)

(d) A system involves four identical ball bearings, each subjected to different radial load in one work cycle as follows:

1. Radial load of 2000 N at 500 rpm for 25% of time.
2. Radial load of 3000 N at 500 rpm for 50% of time.
3. Radial load of 2500 N at 400 rpm for remaining time.

The reliability of the system is 85% for the life of five million revolutions. Determine the dynamic load carrying capacity of the bearing, so as to select it from the manufactures catalogue based on 90% reliability.

[12 marks]

$$\frac{L_{90}}{L_{85}} = \left(\frac{\ln\left(\frac{1}{R_{90}}\right)}{\ln\left(\frac{1}{R_{85}}\right)}\right)^{\frac{1}{1.17}}$$

$$\frac{L_{90}}{L_{85}} = \left[\frac{\ln\left(\frac{1}{0.9}\right)}{\ln\left(\frac{1}{0.85}\right)}\right]^{\frac{1}{1.17}}$$

$$L_{90} = 0.6904\, L_{85}$$

$$L_{85} = 1.44836\, L_{90}$$

$$L_{90} = \frac{L_{85}}{1.44836}$$

$$L_{90} = \frac{5}{1.44836} = 3.45 \text{ MR}$$

$$P_e = \sqrt[3]{\frac{N_1 P_1^3 + N_2 P_2^3 + N_3 P_3^3}{N_1 + N_2 + N_3}}$$

$N_1 = 400 \times 0.25 = 125$ rpm

$N_2 = 90 \times 0.5 = 250$ rpm

$N_3 = 400 \times 0.25 = 100$ rpm

$$P_e = \sqrt[3]{\frac{125 \times 2000^3 + 250 \times 3000^3 + 100 \times 2500^3}{125 + 250 + 100}}$$

$$P_e = 2696.44 \text{ Newton}$$

$L_{90} = \left(\frac{C}{P_q}\right)^3$ ⇒ Ball bearing.

$3.45 = \left(\frac{C}{2696.44}\right)^3$

$C = 4074.4$ Newtn Ans.

12

Q.1 (e) **(i)** The co-ordinates of point P with respect to moving co-ordinate frame are given as $P = [2\ 3\ 5\ 1]^T$. What are the co-ordinates of P with respect to fixed co-ordinates frame, if the moving frame is rotated by 90° about z-axis of fixed frame?

(ii) Determine the rotation matrix for a rotation of 60° about z-axis, followed by a rotation 120° about y axis and a final rotation of 90° about x-axis.

[6 + 6 marks]

${}^1P_2 = [2\ 3\ 5\ 1]^T$

Rotation about 90°

90° ⇒ Anticlockwise

$$\begin{bmatrix} \cos 90 & -\sin 90 & 0 \\ \sin 90 & \cos 90 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$HMT = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{So } P = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \\ 5 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -3 & 0 & 0 \\ 2 & 0 & 0 & 0 \\ 0 & 0 & 5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{So } P = \begin{bmatrix} 0 & -3 & 0 \\ 2 & 0 & 0 \\ 0 & 0 & 5 \end{bmatrix} = \text{Ans}.$$

(ii) $R = R_{x(90)} \cdot R_{y(120)} R_{z(60)}$

$$R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 90 & -\sin 90 \\ 0 & \sin 90 & \cos 90 \end{bmatrix} \begin{bmatrix} \cos 120 & 0 & \sin 120 \\ 0 & 1 & 0 \\ -\sin 120 & 0 & \cos 120 \end{bmatrix} \begin{bmatrix} \cos 60 & -\sin 60 & 0 \\ \sin 60 & \cos 60 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

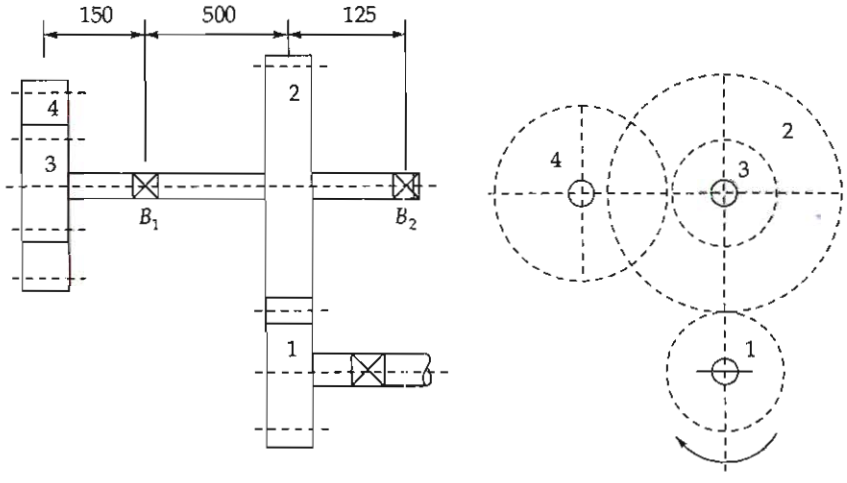
$$R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} -0.5 & 0 & 0.866 \\ 0 & 1 & 0 \\ -0.866 & 0 & 0.5 \end{bmatrix} \begin{bmatrix} 0.5 & -0.866 & 0 \\ 0.866 & 0.5 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} -0.25 & 0.433 & 0.866 \\ 0.433 & -0.749 & -0.5 \\ 0.866 & -0.5 & 0 \end{bmatrix}$$

12

Q.2 (a) A train of spur gears with 20° full depth involute teeth is shown in figure. Gear 1 is the driving gear and transmits 50 kW power at 300 rpm to the gear train. The number of teeth on gears 1, 2, 3 and 4 are 30, 60, 25 and 50 respectively. The module for all gears is 8 mm. Gear 1 is rotating in clockwise direction when seen from the left side of the page. Calculate:

1. Tangential and radial components of tooth forces between gears 1 and 2.
2. Resultant reactions at bearing B_1 and B_2.



(All dimensions are in mm)

[20 marks]

Q.2 (b) Two homogeneous matrices are given:

$$ {}^{j}T_i = \begin{bmatrix} 0.866 & -0.5 & 0 & 11 \\ 0.5 & 0.866 & 0 & -1 \\ 0 & 0 & 1 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad {}^{k}T_i = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & 10 \\ 0 & 0.5 & 0.866 & -20 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

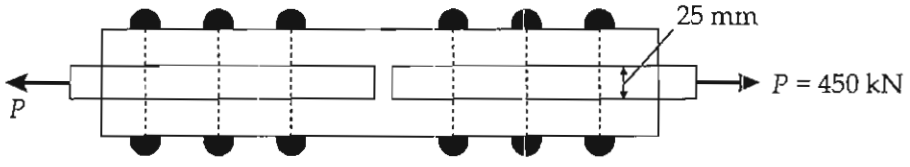
Determine: ${}^{j}T_k$

[20 marks]

Q.2 (c) Explain stepper motor. Briefly discuss the working of the permanent magnet stepper motor with schematic diagram. Also write advantages and disadvantages of stepper motor.

[20 marks]

Q.3 (a) Two tie-bar plates of a bridge structure 25 mm thick, are to be connected by a Lozenge joint double strap to withstand maximum tensile load of 450 kN. The rivets and the plates are made of steel. The permissible stresses in tension, shear and crashing are 80, 60 and 110 N/mm^2 respectively.



1. Determine the diameter of the rivet by using following empirical relationship:

$$d = 6\sqrt{t} \qquad \text{(where } t \text{ and } d \text{ is in mm)}$$

2. Determine the number of rivets. Assume that shear resistance of one rivet in double shear is 1.875 times its resistance in single shear.
3. Show the arrangement of rivets.
4. Find efficiency of joint.

[20 marks]

$P = 450$ kN.

$t = 25$ mm.

$d = 6\sqrt{t}$

$= 6\sqrt{25}$

$d = 30$ mm

$P = (b - d) \times \sigma_{t_{per}}$ $\quad b$ = width.

$450 \times 10^3 = (b - 30) \times 25 \times 80$

$b = 255$ mm

Shear force on one rivet $P_s = k \cdot \frac{\pi}{4} d^2 \tau_{per}$

$= 1.875 \times \frac{\pi}{4} (30)^2 \times 60$

$= 79.52 \times 10^3$ N

$P_s = 79.522$ kN

Crushing force on one rivet $P_c = d \times (\sigma_c)_{per}$

$= 30 \times 25 \times 110$

$= 82.5 \times 10^3$ N

$P_c = 82.5$ kN

Strength of rivet $\Rightarrow$

Min of $(P_s, P_c) = 79.522$ kN

So Number of rivet $= \frac{\text{maximum load}}{\text{Min of } (P_s, P_c)}$

$= \frac{450 \times 10^3}{79.522 \times 10^3}$

$= 5.66$

So no. of rivet $= 6$ bcz of three arrangement.

So for:

Shear force $P_s = 6 \times (P_s)_1$

$= 6 \times 79.522$

$P_s = 477.132$ kN

Crushing force $P_c = 6 \times P_{c_1}$

$= 6 \times 82.5$

$P_c = 495$ kN

tensile force on 1st row

$(P_t)_1 = (p-d) \times \sigma_{t\,per}$

$= (255-30) \times 25 \times 80$

$P_{t_1} = 450$ kN

2nd row

$(P_t)_{II} \Rightarrow (p-2d) \times \sigma_{t\,per} + 1 \times [\text{Min of } P_{s_1} \& P_{c_1}]$

$= (255-2\times30) \times 25 \times 80 + 1 \times 79.522 \times 10^3$

$= (390 + 79.522) 10^3$ Newton

$P_{t_{II}} = 469.522$ kN

$P_{t(III)} = (255-3\times30) \times 25 \times 80 + 3 \times 79.522 \times 10^3$

$P_{t_{III}} = 568.566$ kN

So Min of $(P_{t_{min}}, P_s, P_c) = (P_{t_1})_{min}$

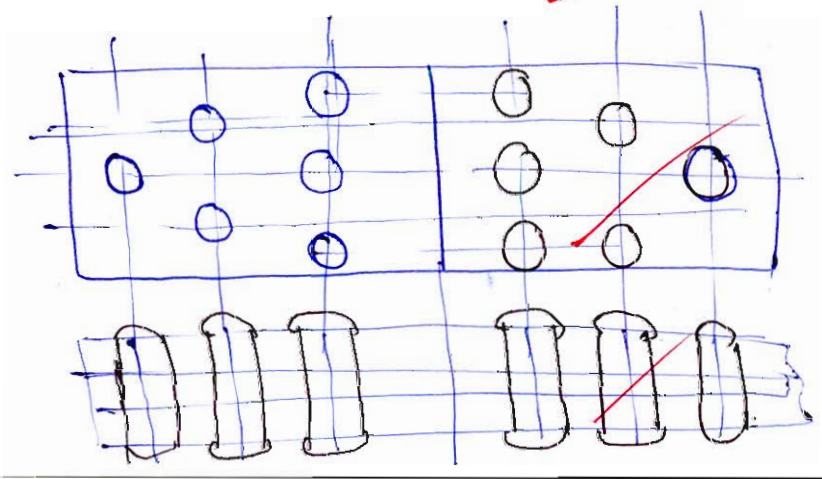
$P_{t_{min}} = 450$ kN

Solid plate strength $P = p \times \sigma_t = 255 \times 25 \times 80 = 510 \times 10^3$ Newton

$= 510$ kN

$\eta = \frac{450}{510}$

$\eta = 88.24\%$



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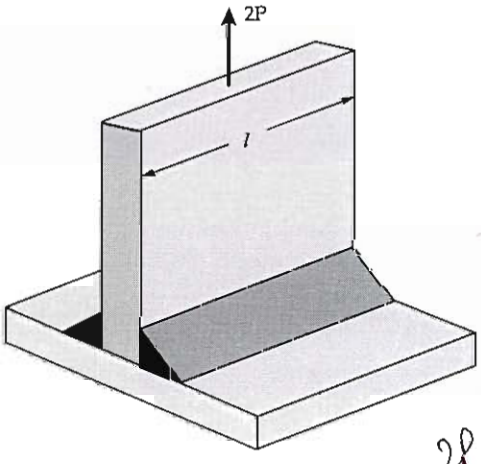
(b) Prove that maximum shear stress in transverse fillet weld is:

$$\tau_{max} = \frac{1.21P}{hl}$$

where, h = size (leg) of fillet weld

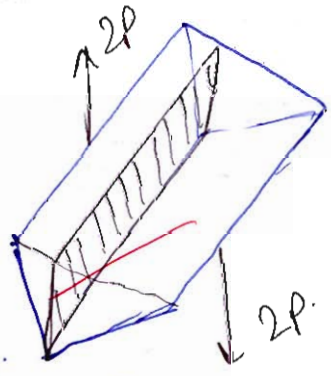
l = length of the weld

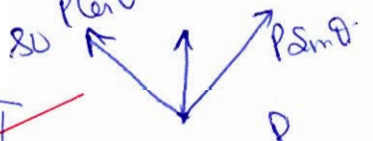
Assume, a double transverse fillet weld of equal legs is subjected to a force 2P as shown in figure.



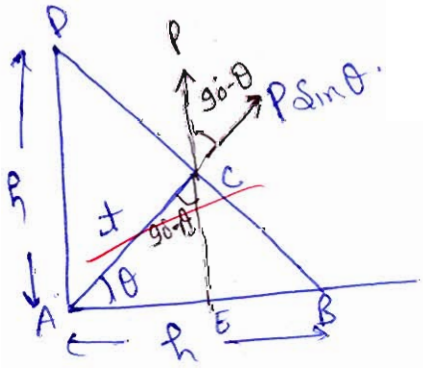
[20 marks]

Transverse fillet weld





t = thickness of the plate



$h = AE = AE + BE$

$h = t\cos\theta + t\sin\theta$

$h = t[\cos\theta + \sin\theta]$

$t = \left(\frac{h}{\sin\theta + \cos\theta}\right)$

$\tau = \frac{2P}{2A}$

$= \frac{2P\sin\theta}{2 \times L h}$

$\tau = \frac{P\sin\theta(\sin\theta+\cos\theta)}{hL}$

$\tau = \frac{P}{A}$ $\quad \tau = P/A$

$\tau = 2[P\sin\theta] \times t \times L$ (Double transverse fillet welds)

here = Double transverse.

$= 2\, P\sin\theta \times L \times \frac{h}{\sin\theta + \cos\theta}$

$\tau = \frac{2\, P \times h \sin\theta}{\sin\theta + \cos\theta}$

for τ_{max} θ will be maximum.

for $\theta_{max/min}$ $\quad \frac{d\tau}{d\theta} = 0$

$\Rightarrow \frac{d}{d\theta}\left[\frac{\sin\theta}{\sin\theta + \cos\theta}\right] = 0$

$\Rightarrow (\sin\theta + \cos\theta)\cos\theta - $

$\tau = 2\, P\sin\theta \times L\,[\sin\theta + \cos\theta]$

$\tau = \frac{2P}{2A} = \frac{2P\sin\theta\, h}{2hL\,(\sin\theta + \cos\theta)}$

$= \frac{P\sin\theta}{hL}[\sin\theta + \cos\theta]$

$\Rightarrow \frac{2P}{2hL}\left[\sin^2\theta + 2\sin\theta\cos\theta\right]$

so $\frac{d\tau}{d\theta} \Rightarrow \frac{d}{d\theta}\left[\frac{2\sin\theta\cos\theta}{2} + \sin^2\theta\right]$

$= \frac{d}{d\theta}\left[\frac{\sin 2\theta}{2} + \sin^2\theta\right]$

$\Rightarrow \frac{2\cos 2\theta}{2} + 2\sin\theta\cos\theta = 0$

$\Rightarrow \cos 2\theta + \sin 2\theta = 0$

$\tan 2\theta = -1$

$2\theta = 135^\circ$

$\theta = 67.5^\circ$

20

$\Rightarrow \tau = \frac{P\sin 67.5\,[\sin(67.5) + \cos(67.5)]}{hL}$

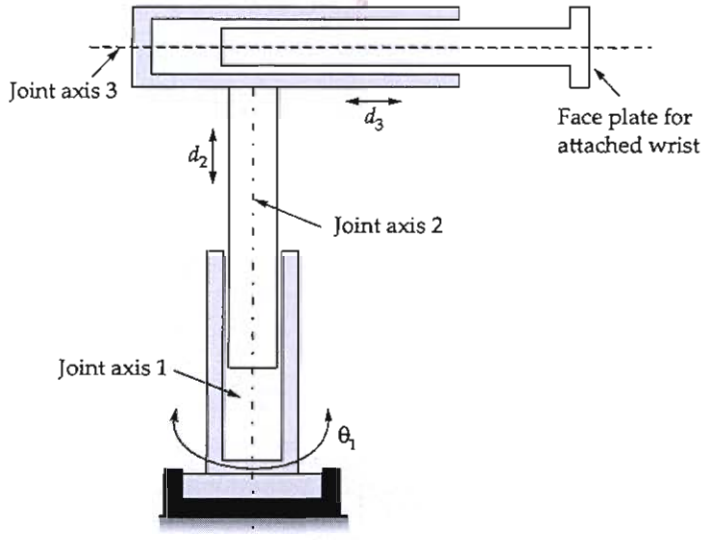
$\tau = \frac{1.21P}{hL}$ MPa.

(c) For the given 3-link cylindrical manipulator.

1 Assign the co-ordinate frames based on D-H representation.

2. Make the D-H parameter table.

3. Prepare the individual and the final composite transformation matrix.



[20 marks]

Q.4 (a) (i) Explain the working principle of piezoelectric sensors and derive the relation shown below:

$v = S_v \times t \times P$

where, v = voltage produced,

S_v = voltage sensitivity

t = thickness of crystal

P = pressure applied

(ii) The following data relate to piezoelectric crystal:

Dimensions - 6 mm × 6 mm × 1.5 mm

Force acting on the pick-up – 6 N

Charge sensitivity – 150 pC/N

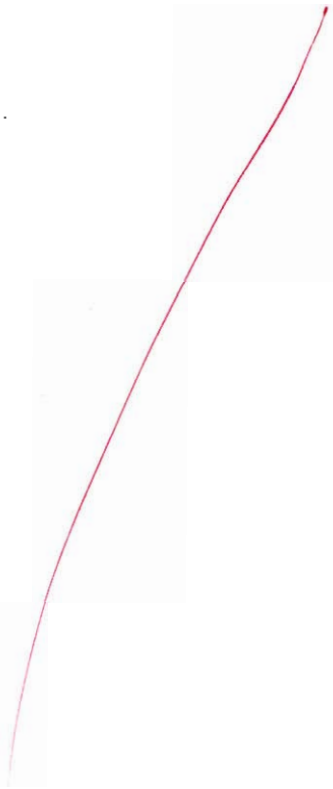
Permittivity (ε) – 12.5×10^{-9} F/m

Modulus of elasticity – 12×10^6 N/m^2

Calculate the following:

1. The charge and capacitance
2. The strain

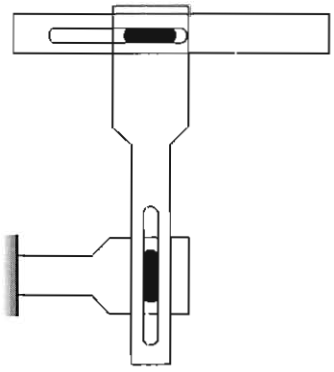
[20 marks]



Q.4 (b) Explain briefly features of intel 8085 microprocessor with the help of a block diagram/architecture.

[20 marks]

Q.4 (c) Consider the two link cartesian manipulator as shown in figure. Derive the forward kinematic equations using the D-H. convention. Make joint link parameter table and also find composite transformation matrices.



[20 marks]

Section B : IC Engine, Renewable Sources of Energy-2+Industrial & Maintenance Engg.-2

Q.5 (a) Establish the relation between maximum torque coefficient and tip speed ratio. What will be the maximum possible value of torque coefficient if the rotor diameter is 50 m, speed of rotor is 40 rpm and upstream wind velocity is 30 m/s?

[12 marks]

$$C_T = \frac{T}{T_{available}}$$

tip Speed ratio $\lambda = \frac{\omega R}{U_{w_1}} \Rightarrow \omega = \frac{\lambda U_{w_1}}{R}$

Torque = F · R

$T = F \cdot R$

and $T = (P/\omega)$ or $P = T \cdot \omega$

for $T_{max} \Rightarrow P_{max}$. [$\omega$ = constant]

So $\Rightarrow P_{max} = \frac{16}{27}\left[P_{available}\right]$

So $\Rightarrow T_{max} \Rightarrow U_{w_2} = \frac{U_{w_1}}{3}$ & $U_{w_b} = \left(\frac{2U_{w_1}}{3}\right)$

$\therefore P_{max} = \frac{1}{2}\rho A_b U_{w_b} U_{w_1}^2$

$T = F \cdot R$

$= \dot{m}_a (U_{w_1} - U_{w_2}) R$

$= \rho A_b U_{w_b} (U_{w_1} - U_{w_2}) R$

$U_{w_b} = \frac{1}{2}(U_{w_1} + U_{w_2})$

$T = \frac{1}{2}\rho A_b \left[U_{w_1}^2 - U_{w_2}^2\right] R$

$T = \frac{1}{2}\rho A_b U_{w_1}^2 R = \left[\frac{\rho \cdot \pi R^2 U_{w_1}^2}{2}\right]$

$P_{max} = \frac{16}{27} \times \left[\frac{1}{2}\rho A_b U_{w_1}^3\right]$

$C_T = \frac{T}{0.593 \times \frac{1}{2}\rho A_b U_{w_1}^3}$

$\omega \Rightarrow \frac{\lambda U_{w_1}}{R}$

$= \frac{TR}{0.593 \times \frac{1}{2}\rho \pi R^2 U_{w_1}^2} = \frac{2T\lambda}{0.593 \rho \pi R U_{w_1}^2}$

$D = 50$ mm

$R = 25$ m

$N = 40$ rpm $\Rightarrow \omega = \frac{2\pi \times 40}{60} = 4.189$ rad/sec

$V_{w_1} = 30$ m/sec

$\lambda = \frac{\omega R}{V_{w_1}}$

$= \frac{4.189 \times 25}{30}$

~~$\lambda = 3.5$~~ $\lambda = 3.49$

So $(C_T)_{max} = \eta = \frac{T_{max}}{T_{available}} = 0.593$

So $T_{max} = \frac{0.593 \times 1.2 \times \pi \times 25 \times (30)^2}{2 \times 3.49}$

$T_{max} = 7206.31$ N-m

proof incomplete

0/5 0/1

Q.5 (b) Compare the emissions from diesel and gasoline engines.

[12 marks]

Diesel engine :

Emission :-

(i) UBHC :- When the combustion procen is not complete so that unburnt carbon are also emitted.

(ii) NOx :- Due to high temperature and availability of oxygen in the sufficient amount so that NOx formation occur.

(iii) CO :- When the oxygen is not available to much or insufficient for burning.

(iv) Particulate matter — Diesel is impure for so that PM 2.5 is form.

(v) SOx & Soot :- Due to sulphur content SOx is also formed.

(vi) Other particle :- so of the other harmful particle is generated / emitted.

Gasoline Engine :-

(i) Due to availability of methane gas is in sufficient amount UBHC [unburnt hydro carbon is generated so that it can take care to UBHC.

(ii) CO Due to Carbon present in the fuel so that CO is also form but in very less amount.

(iii) Generally the gasoline engine work on LPG, CNG gas so that less amount of emission of fuel gases that place

(iii) SO_x :- Due to sulphur content in the gasoline fuel SO_x is formed.

06

compare for more parameter

c) Classify fuel cells on the basis of electrolyte. Explain the working of molten carbonate fuel cell with diagram.

[12 marks]

Fuel Cell:

⇒ It is a electrochemical device in which the chemical energy of the fuel is used to convert the into the electrical energy.

Electrolyte On the basis of electrolyte:

(i) Acidic electrolyte:-

Ede When the electrolyte is in the acidic nature called acidic electrolyte In this electrolyte the $[H^+]$ ion is move in the easy way.

→ $[OH^-]$ is not move in this Solution if it goes so that H_2O will form but they are This type of electrolyte is dangerous they Corrode the material & electrode easily.

Alkaline Electrolyte :

In which the $[OH^-]$ ion is more

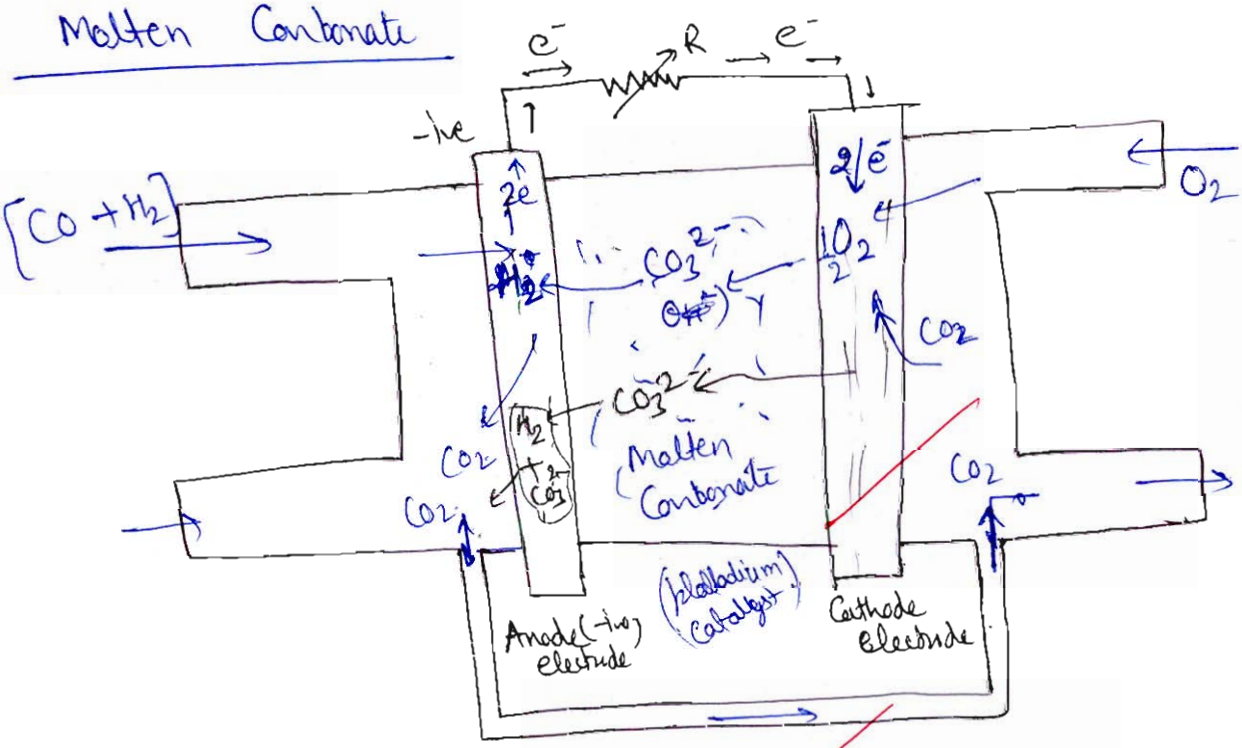
In the easy way.

→ for example KOH in the dilute form.

→ They are less corrode the material & electrode

→ They are most used.

Molten Carbonate



Anode : $H_2 + CO_3^{2-} \longrightarrow H_2O + CO_2 + 2e$

$CO + CO_3^{2-} \longrightarrow 2CO_2 + 2e^-$

Cathode : $\left[CO_2 + \frac{1}{2}O_2 + 2e^- \longrightarrow CO_3^{2-}\right] \times 2$

final

~~$H_2 + CO \longrightarrow H_2O$~~

$H_2 + CO + CO + \frac{1}{2}O_2 \longrightarrow H_2O + CO_2 +$ Power (VI)

↓

Producer gas

Generally Lithium Carbonate is used as the electrolyte.

→ In this the producer gas [$H_2 + CO$] are used

→ In this the Carbonate CO_3^{2-} ion is move in the electrolyte and when it reached at the Anode so they react with H_2 & CO and for CO_2 and H_2O.

before this at Cathode electrone and CO_2 & O_2 is mixed from the Carbonate ion so that boxcar work properly. names of fuel cell??

1) The following observations were recorded during a trial of a four-stroke, single-cylinder oil engine. Duration of trial = 30 min; oil consumption = 4 litres; calorific value of the oil = 43 MJ/kg; specific gravity of the fuel = 0.8; average area of the indicator diagram = 8.5 cm^2; length of the indicator diagram = 8.5 cm; spring constant = 5.5 bar/cm; brake load = 150 kg; spring balance reading = 20 kg; effective brake wheel diameter = 1.5 m; speed = 200 rpm; cylinder diameter = 30 cm; stroke = 45 cm; jacket cooling water = 10 kg/min; temperature rise = 36°C. Calculate: (1) indicated power; (2) brake power; (3) mechanical efficiency; (4) brake specific fuel consumption in kg/kWh and (5) indicated thermal efficiency.

[12 marks]

4 Stroke, Single Cylinder.

$$\dot{m}_f = \rho V = \frac{800 \times 4 \times 10^{-3}}{30} = 0.1067 \text{ kg/min}.$$

$$\text{Area} = L \times H \Rightarrow H = \frac{8.5}{8.5} = 1 \text{ cm}.$$

$$\text{Pressure (P Imep)} = 5.5 \frac{\text{bar}}{\text{cm}} \times 1 \text{ cm} = 5.5 \text{ bar}.$$

$$BP \Rightarrow \text{Brake power} = \frac{2\pi NT}{60}$$

$$= \frac{2\pi \times 200 \times (150 - 20) \times 9.81 \times \frac{1.5}{2}}{60}$$

$BP = 20.03 \times 10^3\ W$

$BP = 20.03\ kW$

$IP = P_{imep} \times V_s$

$= 550 \times \frac{\pi}{4}(0.3)^2 \times 0.45 \times \frac{200}{2 \times 60}$

$IP = 29.158\ kW$

$\eta_{mech} = \frac{BP}{IP} = \frac{20.03}{29.158} = 68.70\%$

$bsfc = \frac{\dot{m}_f}{BP} = \frac{6.4}{20.03}$

$bsfc = 0.3195\ kg/kWh$

$\eta_{ith} = \frac{IP}{\dot{m}_f (CV)_f} = \frac{29.158}{\frac{6.4}{3600} \times 43000}$

$\eta_{ith} = 38.14\%$

12

Q.5 (e) A machine is to be designed to have a minimum reliability of 0.9 and minimum availability of 0.97 over a period of 5000 hour. Calculate the following:

1. Mean time to repair.
2. Probability that machine will fail after 9000 hour.

[12 marks]

$R_{min} = 0.90$

$R_{max} = 0.97$

$T = 5000$ hour.

$\frac{L_{5000}}{L_{9000}} = \left[\frac{\ln \frac{1}{0.9}}{\ln\left(\frac{1}{R_2}\right)}\right]^{\frac{1}{1.17}}$

$\left(\frac{5000}{9000}\right)^{1.17} = \left[\frac{\ln\left(\frac{1}{0.9}\right)}{\ln\left(\frac{1}{R_2}\right)}\right]$

$\ln\left(\frac{1}{R_2}\right) = 0.209578$

Probability $R = 0.8109$

$R_1 = e^{-\lambda t}$

$0.9 = e^{-\lambda \times 5000}$

$\lambda_1 = 2.107 \times 10^{-5}$ / hr.

$R_2 = e^{-\lambda t_2}$

$0.97 = e^{-\lambda \times 5000}$

$\lambda_2 = 6.0918 \times 10^{-6}$ / hr

$\frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

$\lambda \Rightarrow$ $\lambda = 4.7255 \times 10^{-6}$

$T = \frac{1}{\lambda}$

02

(a) A single-basin type tidal power plant has a basin area of 3 km^2. The tide has an average range of 13 m. Power is generated only during the ebb cycle. The turbine stops operating when the head on it falls below 3 m. Calculate the average power generated (in MW) by the plant in single emptying process of the basin if the turbine generator efficiency is 0.7. Estimate the average annual generation of the plant (in kWh). Derive the expression of average power potential. Density of sea water is 1025 kg/m^3.

[20 marks]

b) What do you understand FMECA? Where FMECA can be used? Name the types and main steps of FMECA.

[20 marks]

Q.6 (c) An engine working on an Otto cycle, having a compression ratio of 8, uses octane C_8H_{18} as fuel. The lower heating value of the fuel is 44000 kJ/kg. The air/fuel ratio is 14.5 : 1. Determine the maximum pressure and temperature reached in the cycle.

1. Without considering the molecular expansion.
2. With molecular expansion.

Assume c_v = 0.71 kJ/kgK for all mixture and is constant, compression follows the law $PV^{1.3} = C$, the pressure and temperature of the mixture at the beginning of compression being 1 bar and 60°C respectively. Also determine the percentage molecular expansion.

[20 marks]

a) Explain the process of gasification of solid bio-fuels. What is the general composition of gas produced? Also explain the down-draft type gasifier with a neat sketch.

[20 marks]

Process of gasification :- of solid bio fuel :

→ Gasification is the process in which with the help of waste we can generate the useful gas like methane, butane in the easily and without harmful much more the environment.

→ Methane is the main gas in the bio fuel.

→ In the gasification process ⇒

An-aerobic bacteria is used, and the process is called the fermentation process. in which the with the bacterial action the waste is converted into the gaseous form the gases which generate mainly the methane (CH_4) gas.

General Composition :-

$C_x H_y O_z + H_2O \longrightarrow \underbrace{(CH_4)}_{\text{mainly.}} +$ other waste (Sludge).

In the thermo-Chemical process

Reaction :

$C + \frac{1}{2}O_2 \longrightarrow CO$

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$

$CO + \frac{1}{2}O_2 + H_2O \longrightarrow 2CO + H_2$

$2CO + 2H_2O \longrightarrow CH_4 + CO_2 + O_2$

General Composition of gas produce

Generally C_xH_y * O_2

→ this is the Hydro Carbon produced in the gas form.

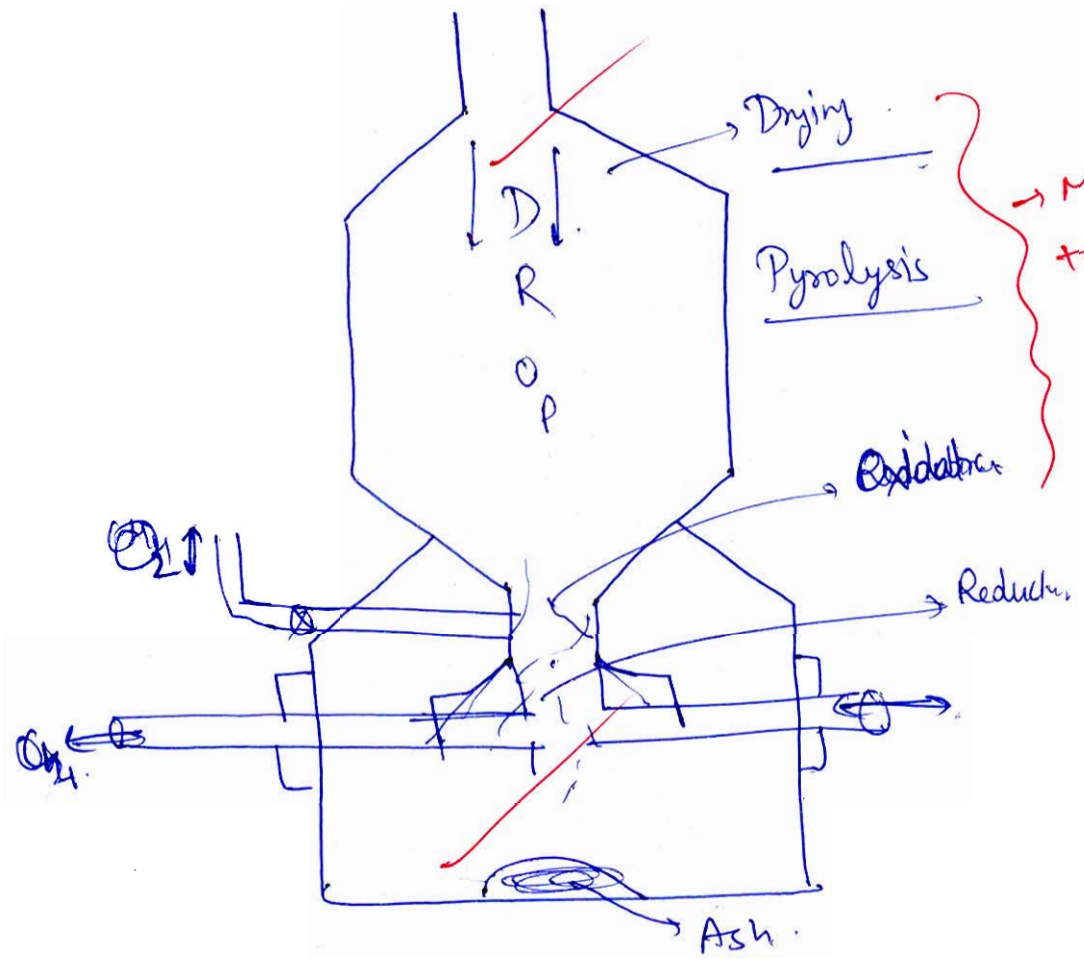
for thermo - Chemical reaction:

Reduction process ⇒

$CO_2 + C \rightarrow 2CO$

$2H_2 + C \rightarrow CH_4$

Down - Draft type Gasifier



In this Drying: It is used for dry the waste. ~~Heat~~ ~~to~~ ~~temperature~~ is approximately 100°C to 120°C

Pyrolysis ⇒ Complex structure converted into the simple structure at 300°C

Reduction : In this the reducing process is occur at the temp of 600°C

Oxidation : In this the oxidation process occur at the temp of 900°C

So in the final the produced gas are produced :

$CO + C \longrightarrow$

and mainly CH_4 produced

compositions !!

12

b) What do you understand by condition based maintenance (CBM)? Classify CBM and name the techniques used for CBM. Also explain the benefits of CBM and essential elements of CBM.

[20 marks]

Condition based maintenance is

→ It is one of the based technique used in the present time for maintenance.

→ In this process the material or machine is test on the basis of condition of working.

→ It is the type of predictive type of maintenance.

→ Condition based maintenance is reduced the chance of breakdown of the machine in a effective way and increase the life of the machine.

In CBM the process used at the working time of the machine so that no handle on the working of the machine.

Technique used for CBM :-

(i) I.R ray (Infra ray)
(ii) Vibration Signature.
(iii) ~~Laser testing~~ Sensor
(iv) Temperature Signature.

specify sensor

(i) IR ray :-

In this the high wavelength ray are incident on the surface of the machine if any defect or breakage start it so that shaw with the help of this type of ray.

(ii) Vibration Signature :

It is one of the effective technique for the reduction of the breakdown of the machine.

→ In this process vibration are generate in the machine so that the small defect is converted into the large defect so that breakage easily find out in the easy way

Sensor → specify

Some of the sensor are effective for measuring the defect and so we can done maintenance process.

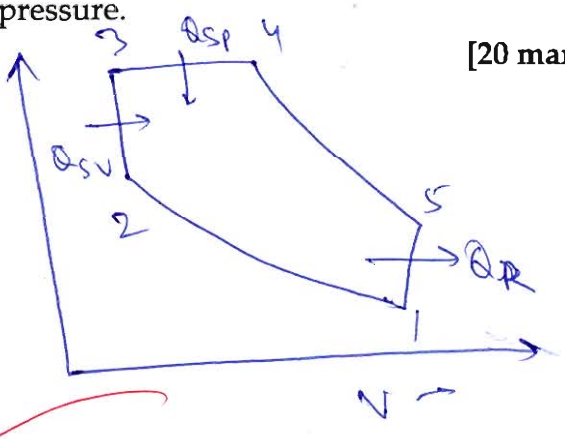
Benefit:

→ Overall cost is less.
→ Reduced the cost of breakage.
→ Less time required.
→ Life of machine increased
→ Easy to handle.
→ Productivity of the machine increase.

12

c) An oil engine works on the dual cycle, the heat liberated at constant pressure being twice that liberated at constant volume. The compression ratio of the engine is 8 and the expansion ratio is 5.3. But the compression and expansion process follow the law $PV^{1.3} = C$. The pressure and temperature at the beginning of compression are 1 bar and 27°C respectively. Assume c_p = 1.004 kJ/kgK and c_v = 0.717 kJ/kgK for air. Find air standard efficiency and the mean effective pressure.

[20 marks]



$T_1 = 300$ K.

$P_1 = 1$ bar

$P_1V_1 = mRT_1$

$V_1 = \frac{0.287 \times 300}{100}$

$V_1 = 0.861 \text{ m}^3/\text{kg}$

$Q_{sp} = 2Q_{sv}$

$r_k = \frac{V_1}{V_2} = 8 \Rightarrow V_1 = 8V_2$

$r_e = 5.3 = \frac{V_5}{V_4}$

$PV^{1.3} = C$

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

$$T_2 = 300 \times (8)^{1.3-1} = 300 \times (8)^{1.3-1}$$

$$\boxed{T_2 = 559.82\ K}$$

$$Q_{SV} = m C_v (T_3 - T_2)$$

$$= 1 \times 0.717 (T_3 - 559.82) \quad \text{---(I)}$$

$$Q_{SP} = 1 \times C_p (T_4 - T_3)$$

$$= 1 \times 1.004 (T_4 - T_3) \quad \text{---(II)}$$

$$r_e = \frac{V_3}{V_4} = 5.3 \qquad [V_1 = V_2]$$

$$\Rightarrow \frac{V_1}{V_4} = 5.3 \Rightarrow V_1 = 5.3 V_4$$

$$P_1 V_1^n = P_2 V_2^n \Rightarrow P_2 = 1 \times (8)^{1.3} = \underline{14.93}\ \text{bar}$$

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right) \quad \& \quad \frac{T_4}{T_3} = \frac{V_4}{V_3}$$

$$r_c = r_e \times r_e \Rightarrow r_c = \frac{V_4}{V_3} = \left(\frac{r_c}{r_e}\right)$$

$$\frac{V_4}{V_3} = \frac{8}{5.3} = \underline{1.5094}$$

$$\frac{T_4}{T_3} = 1.5094 \Rightarrow \boxed{T_4 = 1.5094 T_3}$$

from eqn (2) $\Rightarrow Q_{SP} = 1.004 \times (1.5094 T_3 - T_3)$

$$Q_{SP} = 1.004 \times 0.5094 T_3.$$

& $Q_{SP} = 2 Q_{SV}$

$$1.005 \times 0.5094 T_3 = 2 \times 0.717 (T_3 - 559.82)$$

$$\boxed{T_3 = 870.65\ K}$$

$$T_4 = 1.5094 \times 870.65$$

$$\boxed{T_4 = 1314.159\ K}$$

$$Q_{rej} = mC_v(T_5 - T_1)$$

(4-5)

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

$$\frac{1314.159}{T_5} = (5.3)^{0.3}$$

$$T_5 = 796.829\,K$$

$$\eta = 1 - \frac{Q_{Rej}}{Q_{supply}}$$

Also find Q_{1-2}, Q_{4-5} won't be zero as $PV^{1.3} = C$

$$Q_{supply} = Q_{sv} + Q_{sp}$$
$$= Q_{sv} + 2Q_{sv} = 3Q_{sv}$$
$$= 3 \times 1 \times 0.717 (870.65 - 559.82)$$

$$Q_{supply} = 668.59\ KJ/kg.$$

$$Q_{rej} = 1 \times 0.717 \times (796.829 - T_{cv})$$
$$= 356.226\ KJ/Kg.$$

$$\eta = 1 - \frac{356.226}{668.59}$$

$$\eta = 46.72\%$$

$$\text{Mean effective pressure} = \frac{W_{net}}{V_1 - V_2} = \frac{W_{net}}{V_1\left(1 - \frac{1}{r_2}\right)}$$

$$W_{net} = Q_{net} = 668.59 - 356.226$$
$$= 312.364\ KJ/kg.$$

procedure is correct

08

$$P_{mep} = \frac{312.364}{0.861\left[1 - \frac{1}{8}\right]}$$

$$= 414.6195\ kPa$$

$$P_{mep} = 4.146\ bar.$$ Ans

Q.8 (a) Why is wear debris analysis done? What are wear debris characteristics? Name the different wear mechanisms and wear modes. What are different wear debris methods?

[20 marks]

Wear debris Analysis :

In this process the debris of the wear are used for the calculation or analysis of the defect.

→ Some time the wear occur such that the small particle of the material are see and that are collect for the analysis of the wear.

→ It is one of the easy method for the analysis of wear.

→ with the help of wear debris the collect wear material find out.

Different wear mechanism.

(i) Abrasive wear.
(ii) Adhesion
(iii) Corrosion / oxidation
(iv) Scoring.
(v) Pitting.

Abrasive wear : In this the foreign particle are come in the lubricant and goes with the lubricant to the machine part due to abrasive action the wear occur in the machine.

Adhesive wear :- When the hard material come in contact with the machine so that Adhesive wear occur.

Corrosion :-
Due to oxidation reaction the oxide formation occur so that the corrosion take place.

→ Pitting :- Due to high speed particle strike to the other surface the small hole generate is called pitting.

* Wear debris method :-

(i) Particle Collection :- (Count)
Count the particle it is easy but not accurate.

(ii) Ferromagnetic material :- so that ferrous material are collect but non-ferrous material not collect

(iii) :- Filter :- used ~~sieves~~ filter ~~box~~ so that the particle is collected.

wear debris characteristics ?!?
See Soln.

12

Q.8 (b) A 4-cylinder, 4-stroke diesel engine develops a power of 180 kW. The bsfc is 0.2 kg/kWh. At the beginning of injection pressure is 30 bar and the maximum cylinder pressure is 50 bar. The injection is expected to be at 200 bar and maximum pressure at the injector is set to be about 500 bar. Take the following data:

C_d for injector = 0.75

Specific gravity of fuel = 0.9

Atmospheric pressure = 1 bar

Effective pressure difference = Average pressure difference over the injection period.

Determine the orifice diameter required per injector if the injection takes place over 15° crank angle.

[20 marks]

$K = 4$

4 stroke

$\rho_f = 900 \text{ kg/m}^3$

$BP = 180 \text{ kW}$

$bsfc = 0.2 \text{ kg/kW h}$

$bsfc = \frac{\dot{m}_f}{BP} \Rightarrow 0.2 = \frac{\dot{m}_f}{180}$

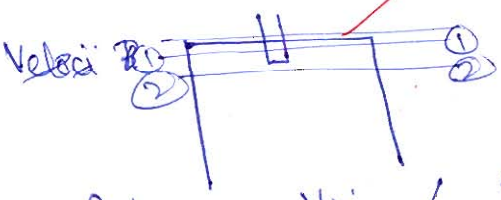
$\dot{m}_f = 0.2 \times 180$

$\dot{m}_f = 36 \text{ kg/hr}$ $\Rightarrow \dot{m}_f = \frac{36}{4}$

$= 9 \text{ kg/hr}$

$P_{inj} = \frac{30 + 50}{2} = 40 \text{ bar}$

$P_{cylinder} = P_{cy} = \frac{200 + 500}{2} = 350 \text{ bar}$



$\frac{P_{inj}}{\rho_f g} + \frac{V_{inj}}{\rho_f g} + z_1 = \frac{P_{cy}}{\rho_f g} + \frac{V_{cy}}{\rho_f g} + z_2$ ($V_{cy} = 0$)

$V_{inj} = \sqrt{\frac{2(P_{cy} - P_{inj})}{\rho_f}}$

$V_{inj} = \sqrt{\frac{2 \times (350 - 40) \times 10^5}{900}}$

$V = 262.47 \text{ m/sec}$

$\theta = 15°$

$C_d = 0.75$

* Energy Conservation

$\dot{m}_{cycle} \times t_{cycle} = \dot{m}_{injector} \, t_{injector}$

$\Rightarrow \frac{36}{3600} \times \frac{9}{3600} \times \frac{4\pi}{\omega} = C_d \rho A V \times \frac{15 \times \frac{\pi}{180}}{\omega}$

$\theta = \omega t \Rightarrow t = \frac{\theta}{\omega}$

$\frac{9 \times 4}{3600} = 0.75 \times 900 \times A \times 262.47 \times \frac{15}{180}$

$\text{Area} = 6.77326 \times 10^{-7}$

$\frac{\pi}{4} d^2 = 6.773 \times 10^{-7}$

$d^2 = 8.624 \times 10^{-7}$

$d = 9.2865 \times 10^{-4}$ m.

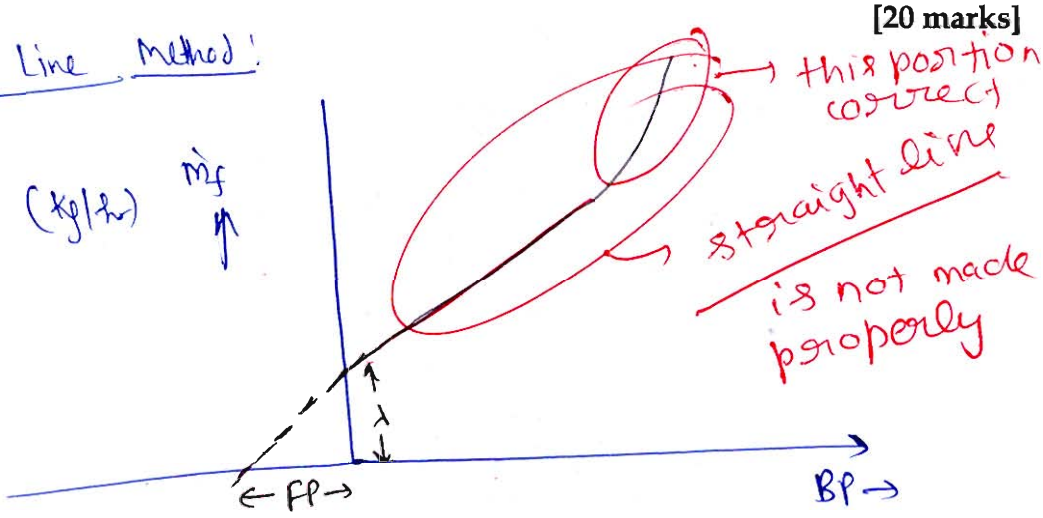
$d = 0.92865$ mm Ans

20

Q.8 (c) Discuss the Willan's line method, the Morse test and motoring test to measure friction power in IC engines. Compare three of them.

[20 marks]

Willan's Line Method:



$\lambda \Rightarrow$ Minimum fuel required to overcome the friction loss (power) in the engine.

→ In this process Single Cylinder IC Engine (CI engine) friction value will be calculated.

→ than after mechanical efficiency we also calculate.

$$BP \propto \boxed{\dot{m}_f = \lambda + x\,(BP)}$$

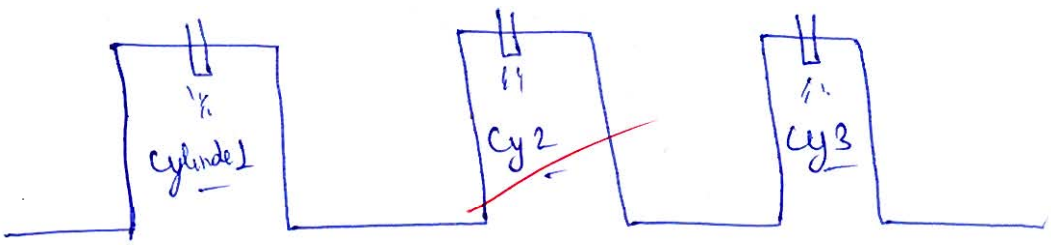
x → slope.

So when $\dot{m}_f = 0$

$$-\lambda = x\,(FP)$$

$$\boxed{FP = -\lambda/x}$$

Morse test:



→ It is used for the multicylinder.
→ for both SI and CI engine.
→ Not for Single Cylinder
→ frictional power Calculation

→ In this the Cut off take place for Calculating single - single cylinder Calculation

→ Cut the fuel from 1st Cylinder than Calculate Indicated power and Brake power

→ Same procedure Repeat till the last Cylnder

1st Cylndr Cut fuel

$$\sum IP \quad \sum_{i=2}^{4} IP = \sum_{i=2}^{4} BP + FP \quad \text{—— (1)}$$

for 2nd Cylndr fuel Cut:

$$IP_1 + \sum_{i=3}^{4} IP = BP_1 + \sum_{i=3}^{4} BP + FP \quad \text{—— (II)}$$

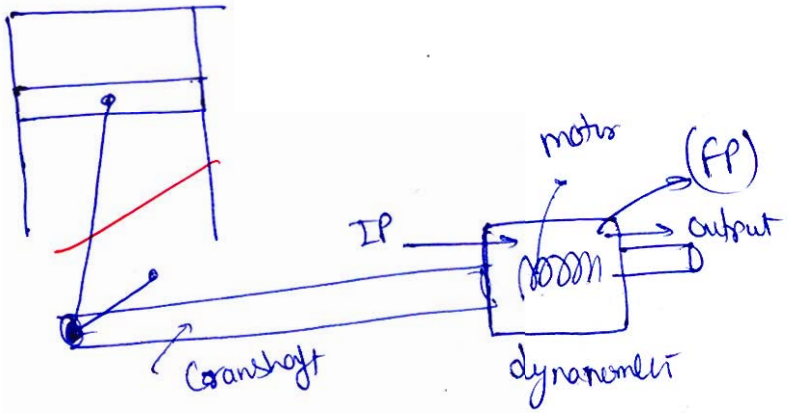
Similarly other

than $IP_i = IP_1 + IP_2 + IP_3 + IP_4$

and $IP = BP + FP$

$$\eta_{mechanical} = \frac{BP}{IP}$$

Motoring test:



→ With the help of motor we can calculate the frictional power of the Cylinder.

→ Electrical circuit will be used

→ Dynamometer is used for the frictional power calculation in the motoring test calculation.

Willian	Morse	Motoring
→ for single cylinder and multi cylinder	Only for multi cylinder	for both type.
→ preferred for the CI engine	for both SI and CI engine	for both SI and CI engine
→ for calculation of frictional power	→ Frictional power	frictional power.
→ Preferred for single cylinder	→ Multi cylinder	→ for both type
→ Not give the accurate result	→ Not full accurate	fully accurate

(18) (17)

○○○○

Space for Rough Work

Space for Rough Work