SECOND SEMESTER EXAMINATIONS

2017/2018 ACADEMIC SESSION

COURSE: ATE 524 – Internal Combustion Engines Design (3 Units)

HOD'S SIGNATURE

CLASS: 500 Level Automotive Engineering

TIME ALLOWED: 3 Hours

INSTRUCTIONS: Answer any **FOUR** questions **Date:** July/August, 2018

Question 1 (General)

a. What are Internal Combustion Engines?

b. Describe the engine piston head in terms of classifications, state its major functions.

c. The coefficient of thermal expansion (CTE) of aluminium is known to be about 2.5 times that of cast iron, what is the implication of this on the clearance between the piston and the cylinder wall.

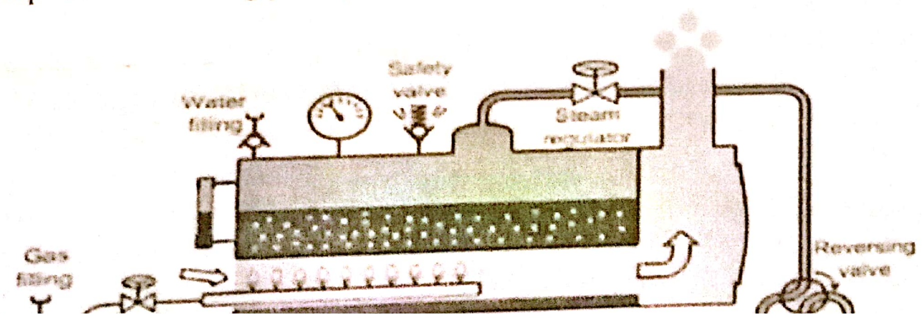
d. Briefly explain pressure lubricating system

e. Distinguish between side (overhung) crankshaft and centre crankshaft

Question 2 (Combustion and Combustion Engines)

a. What are fuels and what is the importance of fuel in combustion?

b. Briefly explain the working principle of a steam locomotive model shown in figure below



Question 3 (Engine Cylinder Design)

a. (i) What are the means of cooling the engine cylinder? (ii) What is the importance of circumferential stress in the engine cylinder designs?

b. A four stroke internal combustion engine has the following specifications: Brake power = 8 kW; Speed = 1200 rpm; Indicated mean effective pressure = 0.35 Nmm^{-2}; Maximum gas pressure = $10P_m$; Mechanical efficiency = 75 %.
Determine: (i) The dimensions of the cylinder, if the length of stroke is 1.5 times the bore of the cylinder; (ii) Wall thickness of the cylinder, if the hoop stress is 35 MPa; (iii) Thickness of the cylinder head and the size of studs when the permissible stresses for the cylinder head and stud materials are 40 MPa and 62 MPa, respectively. Take C as 0.1

D (mm)	75	100	150	200	250	300	350	400	450	500
A (mm)	1.5	2.4	4.0	6.3	8.0	9.5	11.0	12.5	12.5	12.5

Design formulae

$$\eta_{mech} = \frac{BP}{IP}; IP = \frac{p_m lAn}{60}; L_c = 1.15l; t = \frac{P \times D}{2\sigma_c} + A$$

$$t_h = D \times \sqrt{\frac{C \times P}{\sigma_c}}; d_c = \sqrt{\frac{D^2 \times P}{n_s \sigma_t}}; n_s = (0.01D + 4) to (0.02D + 4)$$

$$d_n = 0.75t_f \ to \ t_f; t_f = 1.2t \ to \ 1.4t; d_p = D + 3d_n; \ 19\sqrt{d_n} \leq pitch \leq 28.5\sqrt{d_n}$$

Question 4 (Engine Piston Design)

a. Differentiate between '**piston seizing**' and '***piston slap***'.

b. Design a cast iron trunk type piston for a single acting four stroke engine developing 75 kW per cylinder when running at 600 rpm. The other available data is as follows: Maximum gas pressure = 4.8 N/mm2; Indicated mean effective pressure = 0.65 N/mm2; Mechanical efficiency = 95%; Radius of crank = 110 mm; Fuel consumption = 0.3 kg/BP/hr; Calorific value of fuel (higher) = 44 × 103kJ/kg;
Assume data for the design:
Piston Head: σt = 33.5 MPa; k= 46.6 W/m/°C; (*TC* – *TE*) = 200°C (for cast iron), C= 0.05 **Piston Rings:** Pw = 0.035 MPa; σ_t = 80 MPa (for cast rings); n_r = 4. **Piston Skirt:** μ=0.1, P_b = 0.4 N/mm^2; **Piston Pins:** P_{bl} = 17 N/mm^2, l_l = 0.45 D, d_i = 0.6 d_o, $\sigma_{bperm.}$ = 140 N/mm^2

Design formulae

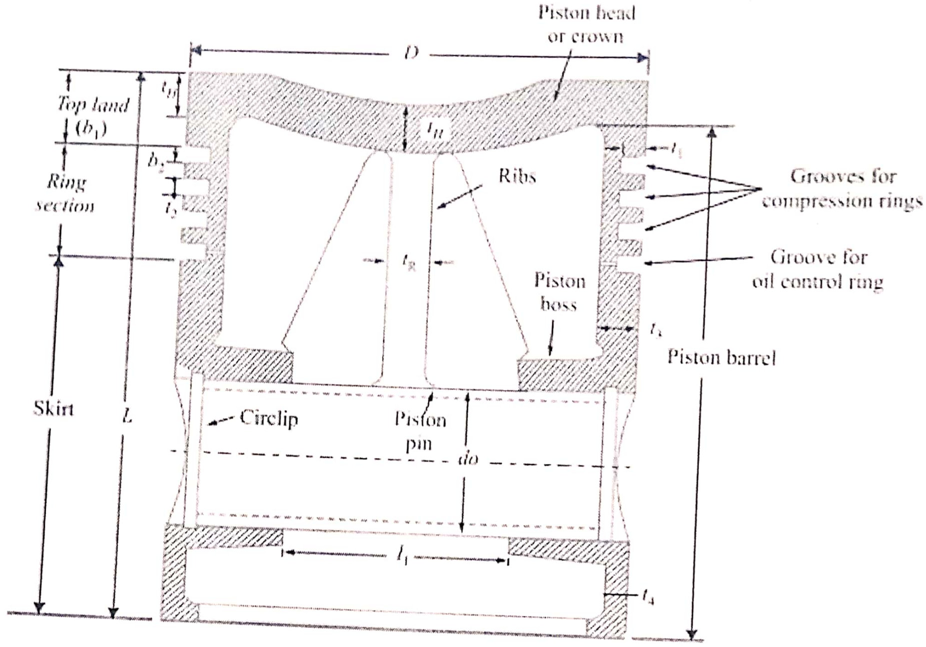
$$t_H = \sqrt{\frac{3PD^2}{16\sigma_t}} by\ strength; t_H = \frac{H}{12.56k(T_c - T_E)} by\ heat\ transfer; H = C \times HCV \times m \times BP$$

$$n = \frac{N}{2}\ for\ 4\ strokes; n = N\ for\ 2\ strokes; IP = \frac{P_m lAn}{60}; \eta_{mech} = \frac{BP}{IP}; t_R = \frac{t_H}{3}\ to \frac{t_H}{2};$$

$$b_1 = t_H to\ 1.2t_H;\ t_1 = D \times \sqrt{\frac{3P_w}{\sigma_t}}; t_2 = 0.7t_1 to\ t_1\ or\ t_2 = \frac{D}{10n_r}; b_2 = 0.75t_2 to\ t_2$$

$$R = \mu \frac{\pi D^2}{4} \times P = P_b \times D \times L_{skirt}; L = b_1 + 4t_2 + 3b_2 + L_{skirt}; b = t_1 + 0.4; t_3 = 0.03\, D + b + 4.5$$

$$t_4 = 0.25 t_3 \, to \, 0.35 t_3; \; F_{LP} = \frac{\pi D^2}{4} \times P = P_{b1} \times d_o \times l_1; M = \frac{F_{LP}}{8} = \frac{\pi}{32}\left[\frac{d_o^4 - d_i^4}{d_o}\right]\sigma_b$$



Question 5 (Engine Connecting Rod Design)

a. What is the name given to a long shank which may be rectangular, circular, tubular, *I*-section or *H*-section, with a small end and a big end? What is the function of such engine part?

b. Design a connecting rod for an I.C. engine running at 1200 r.p.m. and developing a maximum pressure of 3.5 N/mm^2. The diameter of the piston is 110 mm; mass of the reciprocating parts per cylinder 2.5 kg; length of connecting rod 400 mm; stroke of piston 190 mm and compression ratio 5:1. Take a factor of safety of 6 for the design. Take length to diameter ratio for bearing as 1.3 and small end bearing as 2 and the corresponding bearing pressures as 10 N/mm^2 and 15 N/mm^2. The density of material of the rod may be taken as 7500 kg/m^3 and the allowable stress in the bolts as 62 N/mm^2 and in cap as 82 N/mm^2. The rod is to be of I-section for which you can choose your own proportions. Draw a neat dimensioned sketch showing provision for lubrication. ***Use Rankine formula for which the numerator constant may be taken as 315 N/mm^2 and the denominator constant 1 / 7500.*** Assume σ_b (permissible) required for the design as 75 N/mm^2; l =L for both ends hinged; n_b = 2; $t_{b(liner)}$ = 3.

Design formulae

$$\omega = \frac{2\pi N}{60}; I_{xx} = \frac{419}{12} t^4; I_{yy} = \frac{131}{12} t^4; max.\, gas\, force, F_L = F_c = \frac{\pi D^2}{4} \times P;$$

$$Buckling\ load, W_B = F_L \times FOS = \frac{\sigma_c \times A}{1 + a\left(\frac{L}{k_{xx}}\right)^2}; k_{xx} = \sqrt{\frac{I_{xx}}{A}}$$

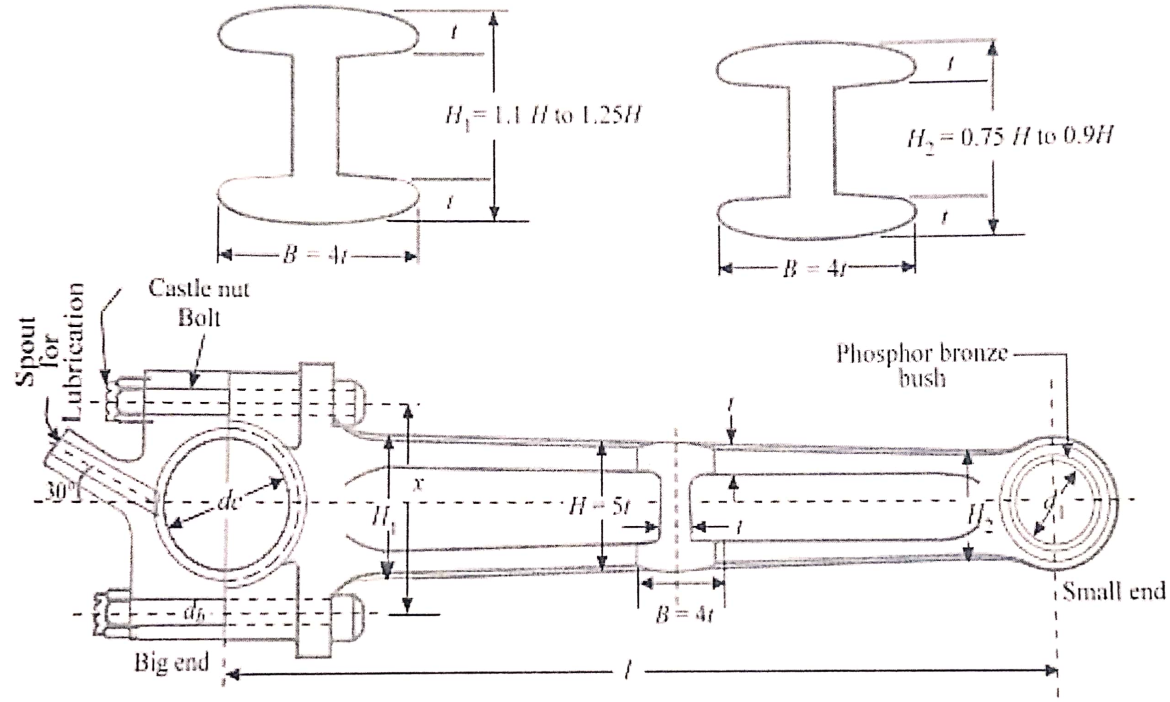
length of crank, $r = \frac{l_{stroke}}{2}$; Crank pin load, $F_c = d_c l_c P_{bc}$; piston pin load, $F_L = d_p l_p P_{bp}$

$d_b = \frac{d_{cb}}{0.84}$; $F_b = \frac{\pi (d_{cb})^2}{4} \times \sigma_{allowable\,(bolt)} \times n_b = F_1$; $F_1 = m_R \omega^2 \left(1 + \frac{r}{l}\right)$

$M_c = \frac{F_1 \times x}{6}$; distance between the bolt centre $x = d_c + 2(t_{b,liner}) + d_b + 3$

$Z_c = \frac{I}{y} = \frac{b_c t_c^2}{6}$; $b_c = l_c$; $\sigma_b = \frac{M_c}{Z_c}$

To check: $m = \rho A l$; $M_{max} = m \omega^2 r \frac{l^2}{9\sqrt{3}}$; $Z_{xx} = \frac{I_{xx}}{5t/2}$; $\sigma_{b,max} = \frac{M_{max}}{Z_{xx}}$



Question 6 (Engine Crankshaft Design)

a. (i) At what angle of the crank will the twisting moment be maximum in the crankshaft?
(ii) What is the main function of the crankshaft?

b. Design a plain carbon steel centre crankshaft for a single acting four stroke single cylinder engine for the following data: Bore = 500 mm ; Stroke = 650 mm ; Engine speed = 500 r.p.m. ; Mean effective pressure = 0.45 N/mm2; Maximum combustion pressure = 3.5 N/mm^2; Weight of flywheel used as a pulley = 70 kN; Total belt pull = 7.5 kN. When the crank has turned through 32° from the top dead centre, the pressure on the piston is 12 N/mm^2 and the torque on the crank is maximum. The ratio of the connecting rod length to the crank radius is 5.

Assumed data required for the design:

b=2D between bearings 1 and 2; $b_1 = b_2 = b/2$; ; $C_1 = C_2 = C/2$;

Crank pin: σ_b = 72 N/mm^2; P_b = 12 N/mm^2;

Left hand crank web: $\sigma_{b,\,allowable}$ = 72 N/mm^2;

Shaft under flywheel: $l_1 = l_2 = l_3$; wf = 320 mm; : $C_{allowable}$ = 820 mm; σb = 45 N/mm^2

Design formulae

Piston gas load, $F_p = \frac{\pi D^2}{4} \times P$; $b_1 = b_2 = \frac{b}{2}$; $b = 2D$

$H_1 = \frac{F_p \times b_1}{b}$; $H_2 = \frac{F_p \times b_2}{b}$; $c_1 = c_2 = \frac{c}{2}$; $V_1 = \frac{W \times c_1}{c}$; $V_2 = \frac{W \times c_2}{c}$

$H_2{}^1 = \frac{(T_1 + T_2)c_1}{c}$; $H_3{}^1 = \frac{(T_1 + T_2)c_2}{c}$;

$M_c = H_1 \times b_2 = \frac{\pi}{32}(d_c)^3\sigma_b$; $l_c = \frac{F_p}{d_c \times P_b}$

$t = 0.65d_c + 6.35\ mm$; $w = 1.125d_c + 12.7\ mm$; $M = H_1\left[b_2 - \frac{l_c}{2} - \frac{t}{2}\right]$; $z = \frac{wt^2}{2}$; $\sigma_b = \frac{M}{z}$;

$\sigma_c = \frac{H_1}{w \times t}$; $\sigma = \sigma_b + \sigma_c$; $l_1 = l_2 = l_3 = 2\left(\frac{b}{2} - \frac{l_c}{2} - t\right)$; $c = l_1 + w_f$; $c_1 = c_2 = \frac{c_{allowable}}{2}$

Bending moment due to weight, $M_w = V_3 \times c_1$

Bending moment due to belt pull, $M_T = H_3{}^1 \times c_1$

Resultant moment on shaft, $M_s = \sqrt{(M_w)^2 \times (M_T)^2} = \frac{\pi}{32}(d_s)^3\sigma_b$