Internal Combustion Engines HomeWork
Form (A)

5.1

1) A five-cylinder, four-stroke cycle SI engine has a compression ratio CR = 11:1, bore B = 5.52 cm, stroke S = 5.72 cm, and connecting rod length L = 11.00 cm. Cylinder inlet conditions are 63°C and 92 kPa. The intake valve closes at 41° aBDC and the spark plug is fired at 15°bTDC. Calculate: (a) Temperature and pressure in the cylinder at ignition, assuming Otto cycle analysis (i.e., assume the intake valve closes at BDC and ignition is at TDC). [K, kPa]; (b) Effective compression ratio (i.e., actual compression of the air-fuel mixture before ignition); (c) Actual temperature and pressure in the cylinder at ignition. [K, kPa]

2) A diesel engine combustion is assumed to begin at inner dead center and to be at constant pressure. The air-fuel ratio is 28:1, the calorific value of the fuel is 42000 kJ/Kg and the specific heat of the products of combustion at constant volume is expressed by the relation C_V = 0.71 + 20*10-5*T kJ/Kg.K where "T" is the temperature in K and "R" for the products = 0.287 kJ/Kg.K. If the compression ratio is 14:1, and the temperature at the end of compression is 800oK, find at what percentage of the stroke the combustion process is completed.

3.8

3) An in-line six, 3.3-liter CI engine using light diesel fuel at an air-fuel ratio = 20 operates on an air-standard Dual cycle. Half the fuel can be considered burned at constant volume, and half at constant pressure with combustion efficiency ηc = 100%. Cylinder conditions at the start of compression are 60°C and 101 kPa. Compression ratio CR = 14:1. Calculate: (a) Temperature at each state of the cycle. [K]; (b) Pressure at each state of the cycle. [kPa]; (c) Cutoff ratio; (d) Pressure ratio; (e) Indicated thermal efficiency. [%]; (f) Heat added during combustion. [kJ/kg]; (g) Net indicated work. [kJ/kg];

3.9

4) The engine in Problem 3 produces 57 kW of brake power at 2000 RPM. Calculate: (a) Torque. [N-m]; (b) Mechanical efficiency. [%]; (c) Brake mean effective pressure. [kPa]; (d) Indicated specific fuel consumption. [gmlkW-hr]

4.21

5) A flexible-fuel vehicle operates with a stoichiometric fuel mixture of one-third isooctane, one-third ethanol, and one-third methanol, by mass. Calculate: (a) Air-fuel ratio. (b) MON, RON, FS, and AKI.

6) It is proposed to design a carburetor for a car. The engine of this car has 796cc displacement volume and develops maximum power at 5500 rpm. The volumetric efficiency at this speed is 70% and the air-fuel ratio is 13.5:1. It is expected that at this peak power, thetheoretical air speed at the throat will reach 105m/a. The coefficint of discharge for the venturi is assumed to be 0.85 while that for the main petrol jet is 0.66. An allowance should be made for the emulsion tube, the diameter of which can be taken as (1/2.5) of the throat diameter. The petrol surface is 6mm below the throat surface. If the fuel to be used has specific gravity of 0.74. Atmospheric conditions are 100kPa and 27 °C. Design a suitable throat and fuel jet sizes.

Q1.A $n_c = 5$; $n_r = 2$; $CR = 11$; $B = 5.52$ cm;
$S = 5.72$ cm; $CRL = 11$; $T_1 = 63°C = 336$ K;
$P_1 = 92$ kPa; $IVC = 41$ abdc; $\theta_{ign} = 15$ bTDC.
$k = 1.4$; $= 221°$ w.r.t. TDC $= 345°$

a) Assuming Otto Cycle; $T_2 = T_{TDC}$, $P_2 = P_{TDC}$

$$\therefore T_2 = T_1 \, CR^{k-1} = 876.8 \text{ K}$$
$$P_2 = P_1 \, CR^{k} = 2640.81 \text{ kPa}$$

b) To find the effective CR; $= \dfrac{V_{ICO}}{V_{ign}}$

$a = S/2 = 2.86$ cm

$$\frac{V_{ICO}}{V_c} = 1 + \frac{1}{2}(CR-1)\left[R + 1 - \cos\theta - (R^2 - \sin^2\theta)^{1/2}\right]$$

$$= 1 + \frac{1}{2}(11-1)\left[\frac{11}{2.86} + 1 - \cos(221) - \left(\left(\frac{11}{2.86}\right)^2 - \sin^2(221)\right)^{1/2}\right]$$

$$= 10.05$$

$$\frac{V_{Ig}}{V_c} = 1 + \frac{1}{2}(11-1)\left[\frac{11}{2.86} + 1 - \cos(345) - (\quad)^{\frac{1}{2}}\right]$$

$$= 1.214$$

$$\therefore CR_{eff} = \frac{V_{Ivc}}{V_{ign}} = \frac{10.05}{1.215} = \underline{8.28}$$

c) $T_{2_{eff}} = T_1 \, CR_{eff}^{k-1} = \underline{\cancel{786}\text{ K}}$

$P_{2_{eff}} = T_1 \, CR_{eff}^{k} = \underline{\cancel{1836}\text{ kPa}}$

1774.3

JORDAN UNIVERSITY
FACULTY OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
METROLOGY & ENG. MEASUREMENTS
Quiz-4, Section-1, First Semester 2009-2010

Dr. Jehad A. A. Yamin **Date :** 25^{th} December, 2010
Max. Points = 25 **Time :** 15 minutes.

ANSWER ***ALL QUESTIONS***

Q1) Below is a table that contains the variation of temperature with resistance. Study it carefully and answer the following questions:

Temperature (C)	15	18	21	24	26.5	29.5	33
Resistance (Ω)	106.06	107.14	108.22	109.3	110.38	111.46	112.75

A) What is the full name of this device? ....

B) It is used for ....

C) Find the linear and quadratic approximation (equations) for each one between the temperature range [15-33 °C].

For constant specific heat, $2933 = 0.71 \times (16/15)(T_3 - 590)$

Solving, we get, $T_3 = 4463$ K

$\therefore$ Maximum pressure in the cycle

$$P_3 = 10.64 \times \frac{4463}{590} = 80.5 \text{ bar} \qquad \textbf{Ans.}$$

3.3. Diesel Engine : Variable specific heat; % stroke in combustion

In a Diesel engine combustion is assumed to begin at inner dead centre and to be at constant pressure. The air-fuel ratio is 28 : 1, the calorific value of the fuel is 42000 kJ/kg, and the specific heat of the products of combustion is given by

$c_v = 0.71 + 20 \times 10^{-5}\,T$; *R for the products* $= 0.287$ *kJ/kg-K.*

If the compression ratio is 14 : 1, and the temperature at the end of compression 800 K, find at what percentage of the stroke combustion is completed.

Solution.

For one kg of fuel the charge is 29 kg and the heating value is 42000 kJ/kg.

$$dQ = m\int_2^3 c_p\, dT$$

and

$$c_p = c_v + R$$
$$= 0.71 + 20 \times 10^{-5}\,T + 0.287$$
$$= 0.997 + 20 \times 10^{-5}\,T$$

$$\therefore \quad \frac{42000}{29} = \int_2^3 (0.997\, dT) + (20 \times 10^{-5}\, T\, dT)$$

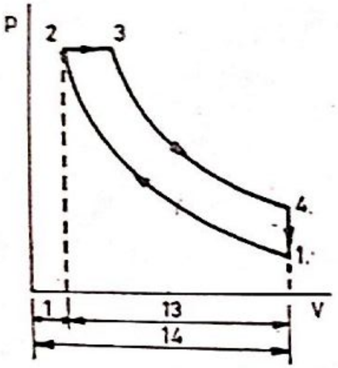


Fig. 3.20.

$$\text{or } 1448.3 = 0.997\,(T_3 - 800) + \frac{20 \times 10^{-5}}{2}(T_3^2 - 800^2)$$
$$= 0.997\,T_3 - 797.6 + \frac{10}{10^5}T_3^2 - 64$$

$$\therefore \quad \frac{10}{10^5}T_3^2 + 0.997\,T_2 - 2309.9 = 0$$

or $T_3 = 1940$ K

$$v_3 = v_2\frac{1940}{800} = 2.4244\, v_2$$

$\therefore$ Combustion occupies

$$= \frac{1.4244}{13} \times 100$$
$$= 10.96\% \text{ stroke} \qquad \textbf{Ans.}$$

3.4 Dual combustion cycle : Effect of variable specific heat

In an oil engine, working on dual combustion cycle the temperature and pressure at the beginning of compression are 90°C and 1 bar. The compression ratio is 13 : 1. The heat supplied per kg of air is 1675 kJ, half of which is supplied at constant volume and half at constant pressure. Calculate (i) the maximum pressure in the cycle, and (ii) the percentage of stroke at which cut off occurs.

Take γ for compression 1.4, R = 0.287 kJ/kg K and c_v for products of combustion $0.71 + 20 \times 10^{-5}\,T$.

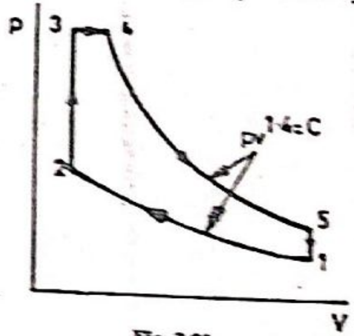


Fig. 3.21

Solution.

(i) $P_2 = P_1\,(v_1/v_2)^\gamma$
$$= 1 \times (13)^{1.4} = 36.3 \text{ bar}$$
$$T_2 = T_1\,(v_1/v_2)^{\gamma - 1}$$
$$= 363\,(13)^{1.4-1} = 1013 \text{ K}$$

During constant volume process 2–3

$$Q_{1-2} = \int_{T_2}^{T_3} c_p\, dT = m\int_{T_2}^{T_3}(0.71 + 20 \times 10^{-5}\,T)\, dT$$

$$\frac{1675}{2} = 1 \times \left[0.71\,T + 20 \times 10^{-5} \times \frac{T_2}{2}\right]_{1013}^{T_3}$$

$$= 0.71\,(T_3 - 1013) + \frac{20 \times 10^{-5}}{2} \times (T_3^2 - 1013^2)$$

Solving we get, $T_3 = 1853$ K

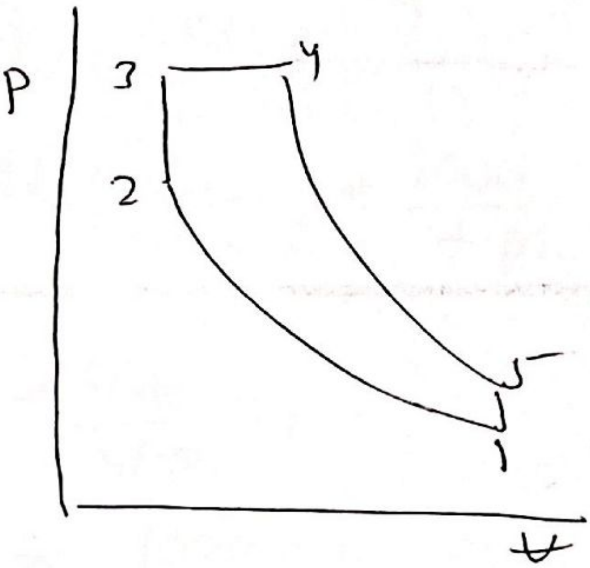
$\therefore$ Maximum pressure, $P_3 = \frac{1864}{1013} \times 36.2$
$$= 66.2 \text{ bar} \qquad \textbf{Ans.}$$

(ii) $$c_p = c_v + R = 0.71 + 20 \times 10^{-5}\,T + 0.287$$

Q3-A $n_c = 6$; $V_s = 3.3\,L$; $(A/F) = 20$; dual cycle;

$CR = 14$; $Q_{in_v} = 50\%\, Q_{in_T}$; $\eta_c = 100\%$; $Q_{HV} = 42500 \frac{kJ}{kg}$;

$P_1 = 101\ kPa$; $T_1 = 333\ K$.



for 1 kg of fuel;

$$\dot m_{Total} = \dot m_a + \dot m_f = 20 + 1 = \underline{21\ kg}$$

$\boxed{1}$ $T_2 = T_1 CR^{n-1} = \underline{957\ K}$

$P_2 = P_1 CR^{n-1} = \underline{4063.5\ kPa}$

$\boxed{2}$ $Q_{in_v} = \frac{\eta_c Q_{HV}}{2} = m_T C_v (T_3 - T_2) \Rightarrow T_3 = \underline{2189.5\ K}$

$\frac{P_3}{P_2} = \frac{T_3}{T_2} \Rightarrow P_3 = \frac{T_3}{T_2} P_2 = \underline{9296.795\ kPa}$

$\boxed{3}$ $Q_{in_p} = \frac{\eta_c Q_{HV}}{2} = m_T C_p (T_4 - T_3) \Rightarrow \underline{T_4 = 3102.77\ K}$

$P_4 = P_3 = \underline{9296.795\ kPa}$

$\boxed{4}$ $v_3 = v_2 = \frac{RT_2}{P_2} = 0.06759\ m^3/kg$

$v_5 = v_1 = \frac{RT_1}{P_1} = 0.94624\ \frac{m^3}{kg}$.

$\beta = \frac{T_4}{T_3} = 1.4171$; $\alpha = \frac{P_4}{P_2} = 2.2878$, $v_4 = \frac{RT_4}{P_4} = 0.0958$

$\boxed{5}$ $T_5 = T_4 \left(\frac{v_4}{v_5}\right)^{n-1} = \underline{1241.276\ K}$

$P_5 = P_4 \left(\frac{v_4}{v_5}\right)^{n} = \underline{376.456\ kPa}$

$Q_{out} = m_T C_v (T_5 - T_1) = 15659.586\ kJ$

$Q_{in} = Q_{cv}$

$\eta_{th} = \underline{63.15\%}$

$W_{net} = \eta_{th} \cdot Q_{in} = \underline{26840.4\ kJ}$

$Y = mx + c$; $m = \frac{\Sigma(x_m Y_m)}{\Sigma(x_m^2)}$; $\bar{x} = \frac{\Sigma x}{n}$;

$x_m = x - \bar{x}$; $Y_m = Y - \bar{Y}$; $\bar{Y} = \frac{\Sigma Y}{n}$;

$Adj = -i\frac{L}{n}$; $R_p = (H_{max} - H_{min}) * \frac{1000}{V \cdot M.}$

$R_z = \left(\frac{\Sigma h_p - \Sigma h_v}{5}\right) * \frac{1000}{V \cdot M.}$;

$R_q(rms) = \sqrt{\frac{\Sigma h_i^2}{n}} * \frac{1000}{V \cdot M.}$;

$Ra = \frac{\Sigma A}{L} * \frac{1000}{V \cdot M.}$; $\dot{Q}_{th}\left(\frac{m^3}{s}\right) = U_{2_{th}} A_2$;

$U_{2_{th}} = \sqrt{\frac{2g\left[\frac{\Delta P_{1-2}}{\gamma_f} + (Z_1 - Z_2)\right]}{1 - \left(\frac{A_2}{A_1}\right)^2}}$; $\dot{Q}_{act} = C_D \dot{Q}_{th}$

$U_2 = \sqrt{\frac{2(P_{stag} - P_{stat})}{\rho}}$; $P_{orifice} = P_{bar} + P_{fan}$;

$\rho_{orifice} = \frac{P_{orifice}}{0.287 * T_{orifice}}$; $\dot{m}_{air\,orif} = C_D \rho_{orif} A_{oriz} \sqrt{\frac{2\Delta P}{\rho}}$

$T_{mean} = \frac{Q_{in} * heatloss * b}{\dot{m}_{air} * C_p * 1753}$, $b = 1422\,mm$;

Every one minute of arc = 20 µm rise/fall in Carrig

Q4 = A

$N = 2000\,rpm$; $\dot{W}_B = 57\,kW$

1) $\dot{W}_B = 2\pi \frac{N}{60} \tau_b \Rightarrow \tau_b = \underline{272\,N\text{-}m.}$

2) $\dot{W}_I = W \times psps \times m \times n_c$

$m_1 = \frac{P_1 V_1}{RT_1}$, $V_1 = V_s + V_c$, $CR = 1 + \frac{V_s}{V_c}$

$V_{s_1} = \frac{3.3\times10^{-3}}{6} = 5.5\times10^{-4}\,m^3$

$V_{c_1} = \frac{5.5\times10^{-4}}{14-1} = 4.23\times10^{-5}\,m^3$

$\therefore V_1 = 5.923\times10^{-4}\,m^3$

$\therefore m_1 = 6.2595\times10^{-4}\,kg$

$\therefore$ ~~$\dot{W}_I = 100.8...kW$~~

$\therefore \eta_m = \frac{57}{80} = \underline{71.25\%}$

$q_{in} = c_v(T_3 - T_2) + c_p(T_4 - T_3)$

$= 2023.281\,\frac{kJ}{kg}$

$Q_{in} = m_a q_{in} n_c$

$= 7.60073\,kJ$

$W_i = \eta_{th} \times Q_{in}$

$= 4.7998\,\frac{kJ}{cyc}$

$\dot{W}_i = 80\,kW$

3) $\dot{W}_b = P_{m_b} \times V_{s\,tot.} \times \frac{N}{60} \frac{1}{n_r}$

$\therefore P_{m_b} = \underline{1036.36\,kPa}$

4) $\frac{m_a}{m_f} = 20$, $m_t = 21 = m_f + m_a$

$m_f = \frac{6.2595\times10^{-4}}{21}\times6 = 1.1788\times10^{-4}$

$\dot{m}_f = m_f \times psps = 2.9807\times10^{-3}$

$bsfc = \frac{\dot{m}_f}{\dot{W}_B} = \underline{0.1882\,\frac{kg}{kW\cdot hr}}$

Scanned by CamScanner

$$Y = mx + c \; ; \quad m = \frac{\Sigma (x_m Y_m)}{\Sigma (x_m^2)} \; ; \quad \bar{x} = \frac{\Sigma x}{n} \; ;$$

$$x_m = x - \bar{x} \; ; \quad Y_m = Y - \bar{Y} \; ; \quad \bar{Y} = \frac{\Sigma Y}{n} \; ;$$

$$Adj = -i \frac{L}{n} \; ; \quad R_p = (H_{max} - H_{min}) * \frac{1000}{V \cdot M.}$$

$$R_z = \left(\frac{\Sigma h_p - \Sigma h_v}{5} \right) * \frac{1000}{V \cdot M.} \; ;$$

$$R_q\,(rms) = \sqrt{\frac{\Sigma h_i^2}{n}} * \frac{1000}{V \cdot M.} \; ;$$

$$R_a = \frac{\Sigma A}{L} * \frac{1000}{V \cdot M.} \; ; \quad \dot{Q}_{th} \left(\frac{m^3}{s}\right) = U_{2_{th}} A_2 \; ;$$

$$U_{2_{th}} = \sqrt{\frac{2g \left[\frac{\Delta P_{1-2}}{\gamma_f} + (Z_1 - Z_2) \right]}{1 - \left(\frac{A_2}{A_1}\right)^2}} \; ; \quad \dot{Q}_{act} = C_D \dot{Q}_{th}$$

$$U_2 = \sqrt{\frac{2 (P_{stag} - P_{stat})}{\rho}} \; ; \quad P_{orifice} = P_{bar} + P_{fan} \; ,$$

$$\rho_{orifice} = \frac{P_{orifice}}{0.287 * T_{orifice}} \; ; \quad \dot{m}_{air\,orif} = C_D \, \rho_{orif} \, A_{orif} \sqrt{\frac{2 \Delta P}{\rho}}$$

$$T_{mean} = \frac{Q_{in} * heat\,loss * b}{\dot{m}_{air} * C_p * 1753} \; , \quad b = 1427\,mm \; ;$$

Every one minute of arc = 20 μm rise/fall in carrig

(4-21)

using values from Table A-2

	mass (m)	molecular weight(M)	moles N=m/M	mole fraction
C_8H_{18}	1	114	0.00877	0.142
CH_3OH	1	32	0.03125	0.506
C_2H_5OH	1	46	0.02174	0.352
			0.06176	1.000

stoichiometric combustion equation for one mole of fuel

$$0.142\ C_8H_{18} + 0.506\ CH_3OH + 0.352\ C_2H_5OH + 3.59\ O_2 + 3.59(3.76)\ N_2 \longrightarrow 2.346\ CO_2 + 3.346\ H_2O + 3.59(3.76)\ N_2$$

(a)

Eqs. (2-55) and (4-1)

$AF = m_a/m_f = N_aM_a/N_fM_f$

$= [(3.59)(4.76)(29)]/[(0.142)(114)+(0.506)(32)+(0.352)(46)]\ \underline{= 10.20}$

(b)

Eqs. (4-11), (4-10) and (4-9)

$MON = ⅓(100) + ⅓(92) + ⅓(89)\ \underline{= 93.7}$

$RON = ⅓(100) + ⅓(106) + ⅓(107)\ \underline{= 104.3}$

$FS = RON - MON = 104.3 - 93.7\ \underline{= 10.6}$

$AKI = (MON + RON)/2 = (93.7 + 104.3)/2\ \underline{= 99}$

(4-22)

(a)

Eq. (4-12) $\quad CN = (23) + (0.15)(77)\ \underline{= 34.6}$

(b)

specific gravity $\quad s_g = \rho/\rho_{water} = 860/997 = 0.863$

Eq. (4-13)

$G = (141.5/0.863) - 131.5 = 32.46$

$T_{mp} = 229°\ C = 444°\ F$

$CI = -420.34 + 0.016\ G^2 + 0.192\ G(\log_{10}T_{mp}) + 65.01(\log_{10}T_{mp})^2 - 0.0001809\ T_{mp}^2$

$= -420.34+(0.016)(32.46)^2+(0.192)(32.46)(\log_{10}[444])+(65.01)(\log_{10}[444])^2-(0.0001809)(444)^2$
$= 32.9$

$\%\ error = [(32.9 - 34.6)/34.6](100)\ \underline{= -4.91\%}$

Q6: $V_s = 796\, cc$; $N = 5500\, rpm$; $\eta_{vol} = 70\%$; $n_r = 2$,
$A/F = 13.5:1$; $U_{2a} = 165\, m/s$, $C_{D_a} = 0.85$; $C_{D_f} = 0.66$
$d_e = \frac{1}{2.5} D_{th}$, $Z_f = 6\, mm$; $SG_f = 0.74$,
$P_1 = 100\, kPa$, $T_1 = 27\,°C$; $n_c = 4$

$$\eta_{vol} = \frac{\dot{m}_{a\,act}}{V_s * ps\,p_s * \rho_a} \quad , \rho_a = \frac{P_a}{RT_a} = 1.1614 \frac{kg}{m^3}$$

$\therefore \dot{m}_{a\,act} = 0.02966\, m^3/s.$

$\therefore \dot{m}_{f\,act} = 2.19713 * 10^{-3}\, m^3/s$

$$U_{2act} = C_D \sqrt{\frac{2}{\rho_f} \Delta P_{1-2}} \qquad \frac{m^2}{s^2} \cdot \frac{kg}{m s^2}$$

$\therefore \Delta P_{1-2} = 5646\, Pa$

$$\dot{m}_f = C_{D_f} \frac{\pi}{4} d_j^2 \sqrt{2 \rho_f (\Delta P_{1-2} - \rho_f g Z_f)}$$

$\therefore d_j =$

Q2 A variable potential divider (potentiometer) has a total resistance of 4 KΩ and is fed from a 10V supply. The output is connected across load resistance of 7 KΩ.

Determine the loading error for the slider positions corresponding to xi/xt = 0.00, 0.2, 0.40, 0.6, 0.8 & 1.00.

Use the results to plot a rough graph of loading error against position ratio xi/xt.

Internal Combustion Engines HomeWork

Form (B)

1) A five-cylinder, four-stroke cycle SI engine has a compression ratio CR = 10:1, bore B = 6.52 cm, stroke S = 6.72 cm, and connecting rod length L = 11.00 cm. Cylinder inlet conditions are 63°C and 95 kPa. The intake valve closes at 40° aBDC and the spark plug is fired at 15°bTDC. Calculate: (a) Temperature and pressure in the cylinder at ignition, assuming Otto cycle analysis (i.e., assume the intake valve closes at BDC and ignition is at TDC). [K, kPa]; (b) Effective compression ratio (i.e., actual compression of the air-fuel mixture before ignition); (c) Actual temperature and pressure in the cylinder at ignition. [K, kPa]

2) A diesel engine combustion is assumed to begin at inner dead center and to be at constant pressure. The air-fuel ratio is 28:1, the calorific value of the fuel is 44000 kJ/Kg and the specific heat of the products of combustion at constant volume is expressed by the relation C_V = 0.71 + 20*10-5*T kJ/Kg.K where "T" is the temperature in K and "R" for the products = 0.287 kJ/Kg.K. If the compression ratio is 16:1, and the temperature at the end of compression is 800oK, find at what percentage of the stroke the combustion process is completed.

3) An in-line six, 3.3-liter CI engine using light diesel fuel at an air-fuel ratio = 20 operates on an air-standard Dual cycle. Half the fuel can be considered burned at constant volume, and half at constant pressure with combustion efficiency ηc = 90%. Cylinder conditions at the start of compression are 60°C and 101 kPa. Compression ratio CR = 16:1. Calculate: (a) Temperature at each state of the cycle. [K]; (b) Pressure at each state of the cycle. [kPa]; (c) Cutoff ratio; (d) Pressure ratio; (e) Indicated thermal efficiency. [%]; (f) Heat added during combustion. [kJ/kg]; (g) Net indicated work. [kJ/kg];

4) The engine in Problem 3 produces 50 kW of brake power at 2200 RPM. Calculate: (a) Torque. [N-m]; (b) Mechanical efficiency. [%]; (c) Brake mean effective pressure. [kPa]; (d) Indicated specific fuel consumption. [gmlkW-hr]

5) A flexible-fuel vehicle operates with a stoichiometric fuel mixture of one-third isooctane, one-third ethanol, and one-third methanol, by mass. Calculate: (a) Air-fuel ratio. (b) MON, RON, FS, and AKI.

6) It is proposed to design a carburetor for a car. The engine of this car has 796cc displacement volume and develops maximum power at 5500 rpm. The volumetric efficiency at this speed is 70% and the air-fuel ratio is 13.5:1. It is expected that at this peak power, thetheoretical air speed at the throat will reach 105m/a. The coefficint of discharge for the venturi is assumed to be 0.85 while that for the main petrol jet is 0.66. An allowance should be made for the emulsion tube, the diameter of which can be taken as (1/2.5) of the throat diameter. The petrol surface is 6mm below the throat surface. If the fuel to be used has specific gravity of 0.74. Atmospheric conditions are 100kPa and 27 °C. Design a suitable throat and fuel jet sizes.

Ans 2-B

diesel engine; $\frac{A}{F} = 28$; $Q_{HV} = 44000\ \frac{kJ}{kg}$;

$C_v = 0.71 + 20\times10^{-5}\,T$, $R = 0.278\ \frac{kJ}{kg\cdot K}$, $CR = 16$

$T_2 = 800K$.

$$dQ = m_f \int C_p\, dT$$

$$C_p = C_v + R$$
$$= 0.997 + 20\times10^{-5}\,T$$

$$\frac{44000}{29} = \int_{T_2}^{T_3} (0.997 + 20\times10^{-5}\,T)\,dT$$

or $1517.24 = 0.997(T_3 - 800) + \frac{20\times10^{-5}}{2}(T_3^2 - 800^2)$

$\therefore T_3 = 1990K$

$$\frac{V_3}{V_2} = \frac{T_3}{T_2} \Rightarrow V_3 = 2.4875\,V_2$$

$$\text{Combustion occupation} = \frac{2.4875}{15} = 0.1658$$

$= 16.58\%$

$$\frac{(dT)}{(dP)_{sat}} = \frac{T v_{fg}}{h_{fg}} \; ; \quad \frac{P^*}{P_o} = \left[\frac{2}{\gamma+1}\right]^{\frac{\gamma}{\gamma-1}} \; ;$$

$$P^* = 0.528\, P_o \; ; \quad \gamma \text{ for air} = 1.4 \; ;$$

$$U_t = \sqrt{\frac{2\gamma R T_o}{\gamma-1}\left[1-\left(\frac{P_t}{P_o}\right)\right]^{\frac{\gamma-1}{\gamma}}} \; ;$$

$$\dot{m}_t = A_t P_o \left(\frac{P_t}{P_o}\right)^{\frac{1}{\gamma}} \sqrt{\frac{2\gamma}{(\gamma-1)RT_o}\left[1-\left(\frac{P_t}{P_o}\right)^{\frac{\gamma-1}{\gamma}}\right]} \; ;$$

$$f = \frac{64}{Re} \; ; \quad h_f = f\frac{L}{D}\frac{U_m^2}{2g} \; ; \quad K = \frac{h_m}{U^2/2g} \; ;$$

$$h_m = \Delta h - h_f \; ; \quad h_m = \Delta h + \left[\frac{U_1^2 - U_2^2}{2g}\right] - h_f \; ;$$

$$Y_{cp} = Y_c + \frac{I_{xx,c}}{Y_c A} \; ; \quad F = \rho g A Y_c \sin\alpha \; ;$$

$$\dot{Q} = -kA\frac{dT}{dx} \; ; \quad \dot{Q} = \dot{m}_w C_{P_w} (T_{out} - T_{in}) \; ;$$

$$C_{P_w} = 4.18\,\frac{kJ}{kg \cdot ^\circ C} \; ; \quad \frac{dT}{dx} = \frac{T_3 - T_4}{L} \; ;$$

T_4 = hot end temperature; T_3 = Cold end tempr.

$$\beta = \frac{\dot{Q}_H}{\dot{W}} = \frac{\dot{Q}_H}{\dot{Q}_H - \dot{Q}_L} \; ; \quad \beta' = \frac{\dot{Q}_L}{\dot{W}} = \frac{\dot{Q}_L}{\dot{Q}_H - \dot{Q}_L} \; ;$$

$$\dot{Q}_L = \dot{m}_a(h_2 - h_1) + \dot{m}_a(\omega_2 h_{g_2} - \omega_1 h_{g_1}) - \dot{m}_c h_c \; ;$$

$$\dot{Q}_c = A_p L \omega \; ; \quad \dot{Q}_c = \frac{0.75}{12.5} * 10^3\, \omega \; ;$$

Ans 3-B $n_c = 5$; $n_r = 2$; $CR = 10$; $B = 6.52$; $S = 6.72$;

$CRL = 11$; $T_1 = 63^\circ C$, $P_1 = 95$ kPa; $IVC = 40$ abdc

$\theta_{ign} = 15$ b TDC. $= 336$ K

a) Assuming Otto cycle:

$$T_2 = T_{TDC} = T_1 CR^{k-1} = 844 \text{ K}$$

$$P_2 = P_{TDC} = P_1 CR^k = 2386.3 \text{ kPa}.$$

b) To find effective $CR = \frac{V_{IVC}}{V_{ign}}$

- $a = S/2 = 3.36$ cm, $\theta_{ign} = 345^\circ$, $\theta_{ivc} = 220$
  $R = CRL/a = 3.273809524$ $= 1.9166\pi$ 1.777π

$$\frac{V_{IVC}}{V_c} = 1 + \frac{1}{2}(10-1)\left[3.2738 + 1 - \cos(220) - \left[3.2738^2 - \sin^2(220)\right]^{\frac{1}{2}}\right]$$

$[5.039844443 - 3.21]$ 9.47782×10^{-3}

$= 9.2339$

- $$\frac{V_{ign}}{V_c} = 1 + \frac{1}{2}(10-1)\left[3.2738 + 1 - \cos(345) - \sqrt{3.2738^2 - \sin^2\theta}\right]$$

$= [3.307883674 - 3.26756]$

$= 1.199444488$

$\therefore CR_{eff} = \frac{V_{IVC}}{V_{ign}} = 7.6984$

$\therefore T_{2_{eff}} = 760.15$ K

$P_{2_{eff}} = 1654.6$ kPa

$$\frac{(dT)}{(dP)_{sat}} = \frac{T v_{fg}}{h_{fg}} \; ; \quad \frac{P^*}{P_o} = \left[\frac{2}{\gamma+1}\right]^{\frac{\gamma}{\gamma-1}} \; ;$$

$$P^* = 0.528\, P_o \; ; \quad \gamma \text{ for air} = 1.4 \; ;$$

$$U_t = \sqrt{\frac{2\gamma R T_o}{\gamma-1}\left[1-\left(\frac{P_t}{P_o}\right)\right]^{\frac{\gamma-1}{\gamma}}} \; ;$$

$$\dot{m}_t = A_t P_o \left(\frac{P_t}{P_o}\right)^{\frac{1}{\gamma}} \sqrt{\frac{2\gamma}{(\gamma-1)RT_o}\left[1-\left(\frac{P_t}{P_o}\right)^{\frac{\gamma-1}{\gamma}}\right]} \; ;$$

$$f = \frac{64}{Re} \; ; \quad h_f = f\frac{L}{D}\frac{U_m^2}{2g} \; ; \quad K = \frac{h_m}{U^2/2g} \; ;$$

$$h_m = \Delta h - h_f \; ; \quad h_m = \Delta h + \left[\frac{U_1^2 - U_2^2}{2g}\right] - h_f \; ;$$

$$Y_{cp} = Y_c + \frac{I_{xx,c}}{Y_c A} \; ; \quad F = \rho g A Y_c \sin\alpha \; ;$$

$$\dot{Q} = -kA\frac{dT}{dx} \; ; \quad \dot{Q} = \dot{m}_w C_{P_w} (T_{out} - T_{in}) \; ;$$

$$C_{P_w} = 4.18 \frac{kJ}{kg \cdot ^\circ C} \; ; \quad \frac{dT}{dx} = \frac{T_3 - T_4}{L} \; ;$$

T_4 = hot end temperature; T_3 = Cold end tempr.

$$\beta = \frac{\dot{Q}_H}{\dot{W}} = \frac{\dot{Q}_H}{\dot{Q}_H - \dot{Q}_L} \; ; \quad \beta' = \frac{\dot{Q}_L}{\dot{W}} = \frac{\dot{Q}_L}{\dot{Q}_H - \dot{Q}_L} \; ;$$

$$\dot{Q}_L = \dot{m}_a (h_2 - h_1) + \dot{m}_a (\omega_2 h_{g_2} - \omega_1 h_{g_1}) - \dot{m}_c h_c \; ;$$

$$\dot{Q}_c = A_p L \omega \; ; \quad \dot{Q}_c = \frac{0.75}{12.5} \times 10^3\, \omega \; ;$$

Internal Combustion Engines HomeWork
Form (C)

1) A six-cylinder, four-stroke cycle SI engine has a compression ratio CR = 10:1, bore B = 7.52 cm, stroke S = 7.72 cm, and connecting rod length L = 11.00 cm. Cylinder inlet conditions are 63°C and 95 kPa. The intake valve closes at 40° aBDC and the spark plug is fired at 15°bTDC. Calculate: (a) Temperature and pressure in the cylinder at ignition, assuming Otto cycle analysis (i.e., assume the intake valve closes at BDC and ignition is at TDC). [K, kPa]; (b) Effective compression ratio (i.e., actual compression of the air-fuel mixture before ignition); (c) Actual temperature and pressure in the cylinder at ignition. [K, kPa]

2) A diesel engine combustion is assumed to begin at inner dead center and to be at constant pressure. The air-fuel ratio is 25:1, the calorific value of the fuel is 44000 kJ/Kg and the specific heat of the products of combustion at constant volume is expressed by the relation C_V = 0.71 + 20*10-5*T kJ/Kg.K where "T" is the temperature in K and "R" for the products = 0.287 kJ/Kg.K. If the compression ratio is 16:1, and the temperature at the end of compression is 800oK, find at what percentage of the stroke the combustion process is completed.

3) An in-line six, 3.3-liter CI engine using light diesel fuel at an air-fuel ratio = 22 operates on an air-standard Dual cycle. Half the fuel can be considered burned at constant volume, and half at constant pressure with combustion efficiency ηc = 95%. Cylinder conditions at the start of compression are 60°C and 101 kPa. Compression ratio CR = 18:1. Calculate: (a) Temperature at each state of the cycle. [K]; (b) Pressure at each state of the cycle. [kPa]; (c) Cutoff ratio; (d) Pressure ratio; (e) Indicated thermal efficiency. [%]; (f) Heat added during combustion. [kJ/kg]; (g) Net indicated work. [kJ/kg];

4) The engine in Problem 3 produces 50 kW of brake power at 2200 RPM. Calculate: (a) Torque. [N-m]; (b) Mechanical efficiency. [%]; (c) Brake mean effective pressure. [kPa]; (d) Indicated specific fuel consumption. [gmlkW-hr]

5) A flexible-fuel vehicle operates with a stoichiometric fuel mixture of one-third isooctane, one-third ethanol, and one-third methanol, by mass. Calculate: (a) Air-fuel ratio. (b) MON, RON, FS, and AKI.

6) It is proposed to design a carburetor for a car. The engine of this car has 796cc displacement volume and develops maximum power at 5500 rpm. The volumetric efficiency at this speed is 70% and the air-fuel ratio is 13.5:1. It is expected that at this peak power, thetheoretical air speed at the throat will reach 105m/a. The coefficint of discharge for the venturi is assumed to be 0.85 while that for the main petrol jet is 0.66. An allowance should be made for the emulsion tube, the diameter of which can be taken as (1/2.5) of the throat diameter. The petrol surface is 6mm below the throat surface. If the fuel to be used has specific gravity of 0.74. Atmospheric conditions are 100kPa and 27 °C. Design a suitable throat and fuel jet sizes.

Ans ① - c $n_c = 5$; $n_r = 2$; $CR = 10$; $B = 7.52$; $S = 7.72$ cm

$CRL = 11$; $T_1 = 63°C$, $P_1 = 95$ kPa ; $IVC = 40°$ aBDC ;

$\theta_{ign} = 15$ bTDC. $= 345°$ $= 220°$

a) Assuming Otto cycle ; $T_2 = T_{TDC}$, $P_2 = P_{TDC}$

$T_2 = T_1 CR^{n-1} =$

$P_2 = P_1 CR^{n-1} =$

b) Taking actual cycle ;

$a = S/2 = 3.86$; $R = \frac{11}{3.86} = 2.849740933$

$\frac{V_{IVC}}{V_c} = 1 + \frac{1}{2}(10-1)\left[2.8497 + 1 - \cos 220 - \sqrt{\quad}\right]$

$= 9.2776838$

$\frac{V_{ign}}{V_c} = 1.2063328$

$\therefore CR_{eff} = 7.69$

$\therefore T_{2eff} = 760.15$ K

$P_{2eff} = 1654.6$ kPa

Ans ② diesel engine; $A/F = 25$; $Q_{HV} = 44000 \frac{kJ}{kg}$

$C_v = 0.71 + 20 \times 10^{-5} T$; $T_2 = 800K$, $R = 0.287$

$C_p = C_v + R$

$= 0.997 + 20 \times 10^{-5} T$

$dQ = m_f \int C_p \, dT$

$$\frac{44000}{26} = \int_{T_2}^{T_3} \left(0.997 + 20 \times 10^{-5} T\right) dT$$

$1692.307 = 0.997(T_3 - 800) + 10 \times 10^{-5}(T_3^2 - 800^2)$

$\therefore T_3 = 2113 K$

$v_3 = 2.64125 v_2$

$\therefore \% = 10.94\%$

CHAPTER 5

Q) $n_c = 5$, ; $n_r = 2$, ; $CR = 11$, ; $B = 5.52$, ; $S = 5.72$ cm

(5-1) $CRL = 11$; $T_1 = 63°C$; $P_1 = 92$ kPa; IVC = 41° abdc,

$\theta_{ign} = 15$ btdc,

(a) Eqs. (3-4) and (3-5)

$T_2 = T_1(r_c)^{k-1} = (336\ K)(11)^{0.35} = \underline{778\ K} = 505°\ C$

$P_2 = P_1(r_c)^k = (92\ kPa)(11)^{1.35} \underline{= 2342\ kPa}$

(b) crankshaft offset = a = S/2 = 5.72/2 = 2.86 cm

$R = r/a = 11.0/2.86 = 3.85$

crank angle when intake valve closes and actual compression starts

$\theta = 180° + 41° = 221°$

crank angle when ignition occurs $\theta = 345°$

using Eq. (2-14) for combustion chamber volume when intake valve closes

$V_{IVC}/V_c = 1 + ½(r_c - 1)[R + 1 - \cos\theta - (R^2 - \sin^2\theta)^{½}]$

$V_{IVC}/V_c = 1 + ½(11 - 1)\{(3.85) + (1) - \cos(221°) - [(3.85)^2 - \sin^2(221°)]^{½}\} = 10.05$

combustion chamber volume when ignition occurs

$V_{ig}/V_c = 1 + ½(11 - 1)\{(3.85) + (1) - \cos(345°) - [(3.85)^2 - \sin^2(345°)]^{½}\} = 1.214$

effective compression ratio

$V_{IVC}/V_{ig} = (V_{IVC}/V_c)/(V_{ig}/V_c) = (10.05)/(1.214) = \underline{\underline{8.28}}$

(c) $T_2 = (336\ K)(8.28)^{1.35-1} \underline{= 704\ K = 431°C}$

$P_2 = (92\ kPa)(8.28)^{1.35} \underline{= 1596\ kPa}$

(5-2)

(a) using Fig. 3-5 and Eq. (3-4)

$T_2 = T_1(r_c)^{k-1} = (333\ K)(10.5)^{0.35} = 758\ K \underline{= 485°\ C}$

(b) Eq. (3-4) $758\ K = (353\ K)(r_c)^{0.35}$ $\underline{r_c = 8.88}$

(c) using Fig.5-19 and Eq.(5-15) with k = 1.4

$T_{2s} = T_1(P_2/P_1)^{(k-1)/k} = (333\ K)(130/96)^{(1.4-1)/1.4} = 363\ K$

Eq. (5-14) $(\eta_s)_{sc} = (T_{2s} - T_1)/(T_{2A} - T_1)$

$0.82 = (363 - 333)/(T_{2A} - 333)$ $T_{2A} = 370\ K = 97°\ C$

$\Delta T = T_{2A} - T_{inlet} = 97° - 80° \underline{= 17°\ C}$

Q3/ $r_c = 6$; $V_d = 3.3\,L$; $\frac{A}{F} = 20$; dual cycle; $Q_{in_V} = \frac{1}{2} Q_{in_{total}}$; $\eta_c = 100\%$; $CR = 14:1$;

(3-8)

(a) (b) using Fig.3-11

$T_1 = 60°\,C = \underline{333\,K}$ given

$\underline{P_1 = 101\,kPa}$ given

Eqs. (3-52) and (3-53)

$T_2 = T_1(r_c)^{k-1} = (333\,K)(14)^{0.35} \underline{= 839\,K} = 566°\,C$

$P_2 = P_1(r_c)^k = (101\,kPa)(14)^{1.35} \underline{= 3561\,kPa}$

Eq. (3-11) with half of heat in at constant volume

$Q_{HV}\eta_c = (AF + 1)c_v(T_x - T_2)$

$\frac{1}{2}(42{,}500\,kJ/kg)(1) = (20 + 1)(0.821\,kJ/kg\text{-}K)(T_x - 839\,K)$

$\underline{T_x = 2072\,K} = 1799°\,C$

Eq. (3-58) with half of heat in at constant pressure

Since $Q_{HV} = \frac{kJ}{kg\ of\ fuel}$

$Q_{HV}\eta_c = (AF + 1)c_p(T_3 - T_x)$

$\frac{1}{2}(42{,}500\,kJ/kg)(1) = (20 + 1)(1.108\,kJ/kg\text{-}K)(T_3 - 2072\,K)$

$\underline{T_3 = 2985\,K} = 2712°\,C$

Eq. (3-78)

$P_x = P_2(T_x/T_2) = (3561\,kPa)(2072/839) \underline{= 8794\,kPa = P_3}$

$v_4 = v_1 = RT_1/P_1 = (0.287)(333)/(101) = 0.9462\,m^3/kg$

$v_3 = RT_3/P_3 = (0.287)(2985)/(8794) = 0.0974\,m^3/kg$

Eqs. (3-64) and (3-65)

$T_4 = T_3(v_3/v_4)^{k-1} = (2985\,K)(0.0974/0.9462)^{0.35} \underline{= 1347\,K} = 1074°\,C$

$P_4 = P_3(v_3/v_4)^k = (8794\,kPa)(0.0974/0.9462)^{1.35} \underline{= 408\,kPa}$

(c) Eq. (3-85)

$\beta = T_3/T_x = 2985/2072 \underline{= 1.441}$

(d) Eq. (3-79)

$\alpha = P_3/P_2 = 8794/3561 \underline{= 2.470}$

(e) Eq. (3-89)

$(\eta_t)_{DUAL} = 1 - (1/r_c)^{k-1}[\{\alpha\beta^k - 1\}/\{k\alpha(\beta - 1) + \alpha - 1\}]$

$\eta_t = 1-(1/14)^{0.35}\{[(2.470)(1.441)^{1.35}-1]/[(1.35)(2.470)(0.441)+2.470-1]\} = 0.589 \underline{= 58.9\%}$

(f) Eq. (3-87)

$q_{in} = c_v(T_x - T_2) + c_p(T_3 - T_x)$

$= (0.821\,kJ/kg\text{-}K)(2072 - 839)K + ((1.108\,kJ/kg\text{-}K)(2985 - 2072)K \underline{= 2024\,kJ/kg}$

(g) $w_{net} = \eta_t q_{in} = (0.589)(2024\,kJ/kg) \underline{= 1192\,kJ/kg}$

Q4

(3-9) $N = 2000\ rpm$; $\dot{W}_B = 57\ kW$;

(a)

using Fig.3-11

Eq. (2-43)
$\dot{W} = 2\pi N\tau = 57\ kJ/sec = (2\pi\ radians/rev)(2000/60\ rev/sec)\tau$
$\tau = 0.272\ kN\text{-}m = \underline{272\ N\text{-}m}$

(b)

for 1 cylinder
$V_d = (0.0033\ m^3)/6 = 0.00055\ m^3$

Eq. (2-12) $r_c = (V_d + V_c)/V_c = 14 = (0.00055 + V_c)/V_c$
$V_c = 0.000042\ m^3$

$V_1 = V_d + V_c = (0.00055\ m^3) + (0.000042\ m^3) = 0.000592\ m^3$

mass in 1 cylinder
$m_1 = P_1V_1/RT_1 = (101)(0.000592)/(0.287)(333) = 0.000626\ kg$

using q_{in} and η_t values from Problem 3-8
$Q_{in} = mq_{in} = (0.000626\ kg)(2024\ kJ/kg)(6\ cyl) = 7.602\ kJ/cycle$

$(W_i)_{net} = \eta_t Q_{in} = (0.589)(7.602\ kJ/cycle) = 4.48\ kJ/cycle$

Eq. (2-42)
$\dot{W}_i = WN/n = (4.48\ kJ/cycle)(2000/60\ rev/sec)/(2\ rev/cycle) = 74.7\ kW$

Eq. (2-47) $\eta_m = \dot{W}_b/\dot{W}_i = 57/74.7 = 0.763 = \underline{76.3\%}$

(c)

Eq. (2-41)
$\tau = (bmep)V_d/4\pi = 272\ N\text{-}m = bmep(0.0033\ m^3)/4\pi$ $\underline{bmep = 1036\ kPa}$

(d)

with AF = 20, mass of fuel will be (1/21) of total mass
$m_f = (0.000626\ kg/cyl\text{-}cycle)(1/21)(6\ cyl) = 0.00018\ kg/cycle$

$\dot{m}_f = (0.00018\ kg/cycle)(2000/60\ rev/sec)/(2\ rev/cycle)$
$= 0.003\ kg/sec = 10.8\ kg/hr = 10{,}800\ gm/hr$

Eq. (2-60)
$bsfc = \dot{m}_f/\dot{W}_b = (10{,}800\ gm/hr)/(57\ kW) = \underline{189\ gm/kW\text{-}hr}$

11.5. Choke and main jet size for Fiat car engine

The Fiat Padmini car has a four stroke engine of 1089 cc capacity. It develops maximum power 32 kW at 5000 r.p.m. The volumetric efficiency at this speed is 75% and the air-fuel ratio 13 : 1, At peak power the theoretical air speed at the choke is 120 m/s. The coefficient of discharge for the venturi is 0.85 and that of the main petrol jet is 0.66. An allowance should be made for the emulsion tube, the diameter of which can be taken as 1/2.5 of the choke diameter. The petrol surface is 6 mm below the choke at this engine condition. Calculate the sizes of a suitable choke and main jet. The specific gravity of petrol is 0.75 and the atmospheric pressure 1.03 bar and temperature 27°C. [D = 23.2 mm, d = 1.296 mm]

11.6. Carburettor Maruti Car.

Q6

It is proposed to design a carburettor for Maruti Car. The four stroke petrol engine has a displacement of 796 cm^3 and develops maximum power at 5500 rev/min. The volumetric efficiency at this speed is assumed to be 70% and the air-fuel ratio is 13.5 : 1.

It is expected that at peak power the theoretical air speed at the choke will be 105 m/s. The coefficient of discharge for the venturi is assumed to be 0.85 and that of the main petrol jet is 0.66. An allowance should be made for the emulsion tube, the diameter of which can be taken as 1/2.5 of the choke diameter. The petrol surface is 6 mm below the choke at this engine condition. Calculate the sizes of a suitable choke and main jet. The specific gravity of petrol is 0.74. Atmospheric pressure and temperature are 1 bar and 27°C respectively. [21.3 mm, 1.183 mm]

11.7. Carburettor, no lip : size of venturi and fuel orifice (approximate method)

A 8.25 cm × 11.5 cm, four-cylinder, four stroke cycle spark-ignition engine is to have a maximum speed of 3000 rpm and volumetric efficiency of 80%. If the maximum venturi depression is to be 150 cm of water what must be the size of the venturi? Also determine the size of the fuel orifice if air-fuel ratio of 14 : 1 is desired. List the assumptions made.

Take coefficient of discharge for air and fuel orifices as 0.84 and 0.7 respectively. Density of air 1.29 kg/m^3 and density of fuel 700 kg/m^3.

[22.2 mm, 1.35 mm]

11.8. Carburettor : effect of air cleaner on air-fuel ratio (approximate method)

A carburettor in which the float chamber is vented to atmosphere is tested in the factory without an air cleaner. The main metering system of the carburettor is found to give a fuel-air ratio of 0.066 at the sea level conditions. Atmospheric pressure 1.013 bar. The pressure at the venturi throat is 0.814 bar. The carburettor is tested again when an air cleaner is fitted at inlet to the carburettor. The pressure drop due to air cleaner is found to be 0.039 bar when the air flow at sea level condition is 245 kg/hr. Pressure at sea level is 1.013 bar.

Assuming negligible nozzle lip and constant coefficient of flow and constant air flow, calculate

(a) throat pressure when the air cleaner is fitted.

(b) Fuel-air ratio when air cleaner is fitted. [0.775 bar; 0.0722]

11.9. Carburettor : effect of altitude.

Determine the air-fuel ratio at 4570 m altitude in a carburettor adjusted at sea level for a 15.2 : 1 ratio. Air temperature 20°C and pressure 1.013 bar at sea level.

The temperature of the air decreases with altitude given by the expression

$$t = t_s - 0.0065\,h, \quad \text{where } h = \text{height in m}$$

$$t_s = \text{sea level temperature in °C}$$

The air pressure decreases with altitude as per relation

$$h = 19220 \log_{10}\left(\frac{1.013}{p}\right), \quad \text{where} \quad p = [12.19] \text{ bar}$$

State any assumptions made.

JORDAN UNIVERSITY
FACULTY OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
Automotive Engineering (944441)
Second Test, First Semester 2004/2005

Dr. Jehad A. A. Yamin **Date :** 28th December, 2002
Time : 15 minutes.

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Q1: Answer the following:

(A) What are the main functional requirements of an injector? **(5 Points)**

(B) An 8 cylinder, 4-stroke diesel engine has power ouput of 400 kW at 1000 rpm. The fuel consumption is 0.265 kg/kW-hr. The pressure inside the cylinder at the beginning of injection is 40bar and the maximum pressure inside the cylinder is 70bar. The injector begins injection at pressure of 250 bar and the maximum injection pressure is 650bar. Calculate the orifice area required per injector if the injection duration lasts for 12 degrees of crank angle. Take the coefficient of discharge for injector as 0.6, specific gravity of fuel as 0.85 and the atmospheric pressure as 1.013bar. Thke the effective pressure difference to be the average pressure difference over the injection period. **(20 Points)**

$n_c = 8$, $n_r = 2$, $BP = 400\,kW$, $N = 1000\,rpm$

$P_{cyl} = 40\,bar$ to $70\,bar$, $bsfc = 0.265\,kg/kW \cdot h$

$P_{inj} = 250$ to $650\,bar$

$\theta = 12^\circ$, $C_D = 0.6$, $SG = 0.85$,

$P_{atm} = 1.013\,bar.$

$$\Rightarrow \Delta P = \frac{(250-40)+(650-70)}{2} = \underline{395\,bar}$$

$$u_f = C_{D_f}\sqrt{\frac{2}{\rho_f}\Delta P} = \cancel{182.96}\ 182.917\ m/s \quad 4$$

$$Time = \frac{\theta}{360}\cdot\frac{60}{rpm} = \underline{2\times10^{-3}\ sec.} \quad 4$$

$$rps = \frac{N}{60}\frac{1}{n_r} = \underline{8.334} \quad 4$$

$$\dot{Q} = \frac{\dot{m}_f}{\rho_f} = \frac{bsfc * BP}{\rho_f} = 0.1247 \text{ for 8 cyl.}$$

$$= 0.015588 \ m^3/hr \text{ for 1 cyl}$$

$$= \underline{\underline{4.33 \times 10^{-6} \ m^3/s}} \qquad 5$$

$$\dot{Q} = \left(\frac{\pi}{4} * d_o^2 * n\right) * U_f * \left(\frac{\theta}{360} \cdot \frac{60}{N}\right) * psps$$

$$d_o = \sqrt{\frac{\dot{Q}}{U_f * \left(\frac{\theta}{360} \ \frac{60}{N}\right) * psps} \ \frac{4}{\pi} \ \frac{1}{n}}$$

$$= 1.344 \times 10^{-3} m$$

$$\boxed{d_o = 1.344 \ mm} \qquad 5$$

JORDAN UNIVERSITY
FACULTY OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
Automotive Engineering (944443)
Quiz-2

Dr. Jehad A. A. Yamin

Date : 23rd December, 2002

Time : 15 minutes.

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Q: An experimental four-stroke gasoline engine of 1.7L capacity is to develop maximum power at 5000 RPM. The volumetric efficiency is 75% and air-fuel ratio is 14:1. Two carburetors are to be fitted (each handling same amount of air) and it is expected that at the maximum power the air speed at the throat reaches100m/s. The coefficient of discharge for the venture is assumed to be 0.8 and that of the main jet is 0.65. An allowance should be made for the emulsion tube, the diameter of which can be taken as 1/3 of the choke diameter. The gasoline surface is 6mm below the choke at this engine condition. Taking the compressibility into account, calculate the pressure drop across the choke, the size of the suitable choke and main jet. The specific gravity of the gasoline is 0.75, atmospheric conditions are 100kPa and 300K, Cp = 1.005 kJ/kg.K, R=0.287 kJ/kg.K. **(5 Marks)**

$$U_{2a} = C_{Da}\sqrt{2C_pT_1\left[1-P_R^{\frac{k-1}{k}}\right]}, \quad k = C_p/C_v$$

$$P_R = (P_2/P_1)$$

$$U_{2f} = C_{dj}\sqrt{2\left(\frac{P_1-P_2-\rho_f g z_f}{\rho_f}\right)}$$

$$\dot{m} = \rho \cdot A \cdot U$$

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Ans $\Longrightarrow$

Ans Actual Vol^m of air sucked per second ($\dot{V}_a$)

$$= \eta_v * V_s * \frac{N}{60} * \frac{1}{2}$$

$\therefore \dot{V}_a = 0.053125 \ m^3/s$ ——— $\frac{1}{2}$

Air flow thro each Carb at atmospheric Condition ($\dot{V}_1$) =

$$= \frac{\dot{V}_a}{2} = 0.02656 \ m^3/s$$ ——— $\frac{1}{2}$

Now to find $\dot{m}_a = \rho_a \dot{V}_1$

but $\rho_a = \frac{P_a}{RT_a} = 1.16 \ kg/m^3$ ——— $\frac{1}{2}$

$\therefore \dot{m}_a = 0.0308 \ kg/s$ ——— $\frac{1}{2}$

Now let us find $U_{2_{th}}$

$$= \sqrt{2 C_p T_1 \left[1 - (P_R)^{\frac{k-1}{k}}\right]} \quad \text{where } P_R = \frac{P_2}{P_1}$$

$\therefore P_R = 0.943$ ——— $\frac{1}{2}$

or $P_2 = 94.3 \ kPa \Rightarrow \Delta P_k = 0.057$ bar — $\frac{1}{2}$

Since flow Compressibility is to be taken into effect

$\therefore \dot{V}_{2a}$ has to be found $= \dot{V}_a \left(\frac{P_1}{P_2}\right)^{\frac{1}{k}}$

$= 0.0276 \ m^3/s$ ——— $\frac{1}{2}$

or $\dot{V}_{2a} = C_{Da} U_{2_{th}} A_{th} \Rightarrow A_{th} = 3.45 \ cm^2$

$= \frac{\pi}{4}(D_{th}^2 - d_e^2)$

or $D_{th} = 2.22 \ cm$ ——— $\frac{1}{2}$

JORDAN UNIVERSITY
FACULTY OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
Automotive Engineering (944443)
Quiz-2

Dr. Jehad A. A. Yamin
Time : 15 minutes.

Date : 23rd December, 2002

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Q: An experimental four-stroke gasoline engine of 1.7L capacity is to develop maximum power at 5000 RPM. The volumetric efficiency is 75% and air-fuel ratio is 14:1. Two carburetors are to be fitted (each handling same amount of air) and it is expected that at the maximum power the air speed at the throat reaches 100m/s. The coefficient of discharge for the venture is assumed to be 0.8 and that of the main jet is 0.65. An allowance should be made for the emulsion tube, the diameter of which can be taken as 1/3 of the choke diameter. The gasoline surface is 6mm below the choke at this engine condition. Taking the compressibility into account, calculate the pressure drop across the choke, the size of the suitable choke and main jet. The specific gravity of the gasoline is 0.75, atmospheric conditions are 100kPa and 300K, Cp = 1.005 kJ/kg.K, R=0.287 kJ/kg.K. **(5 Marks)**

$$U_{2a} = C_{Da}\sqrt{2C_pT_1\left[1-P_R^{\frac{k-1}{k}}\right]}, \quad k = C_p/C_v$$

$$P_R = (P_2/P_1)$$

$$U_{2f} = C_{dj}\sqrt{2\left(\frac{P_1-P_2-\rho_f g z_f}{\rho_f}\right)}$$

$$\dot{m} = \rho \cdot A \cdot U$$

Continue Solution

$$\therefore \dot{m}_f = \frac{\dot{m}_a}{A/F} = 0.00022\ \text{kg/s} \quad \frac{1}{2}$$

$$= C_{Df} A_j \sqrt{2\rho_f(\Delta P - \rho_f g z_f)}$$

$$\therefore A_j = 0.01162\ \text{cm}^2$$

$$\therefore d_j = 1.22\ \text{mm} \quad \frac{1}{2}$$

JORDAN UNIVERSITY

FACULTY OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

Automotive Engineering (944443)

Quiz-2

Dr. Jehad A. A. Yamin **Date :** 12th December, 2004

Time : 25 minutes.

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Q1: Determine the air-fuel ratio upplied at 5 Km altitude by a carburettor which is adjusted to give an air-fuel ratio of 14:1 at sea level where air temperature is 27 C and pressure is 1.013 bar.

The temperature of air decreases with altitude as given by the following equation : $\mathbf{T_h = T_{calib} - 0.0065 * h}$

And the air pressure decreases with altitude as per the following relation :

$$\mathbf{h = 19200 \log_{10} (1.013/P)}$$

Also calculate the degree of enrichment (E). Also draw a curve showing the variation of F/A ratio with altitude. **(12 Points)**

$$T_{5000\,m} = 27 - 0.0065 * 5000$$
$$= -5.5\ ^\circ C$$
$$= 267.5\ K \quad 2$$

$$h = 19200 \log_{10}\left(\frac{1.013}{P_h}\right)$$

$$\therefore P_h = \frac{1}{10^{\frac{h}{19200}}} = 0.5566\ bar \quad 2$$

$$\rho_{calib} = \frac{P_{calib}}{R\,T_{calib}} = \frac{1.013 * 10^5}{0.287 * 1000 * 300}$$
$$= 1.1765\ kg/m^3 \quad 2$$

$$\rho_h = \frac{P_h}{R T_h} = 0.725\ kg/m^3 \quad 2$$

$$(A/F)_h = (A/F)_{calib} * \sqrt{\frac{\rho_h}{\rho_o}} = 10.99 \quad 2$$

$$E + 1 = \sqrt{\frac{\rho_o}{\rho_h}} \Rightarrow E = 27.35\% \quad 2$$

Q2: A 10 cm diameter and 12 cm stroke, 4-cylinder, 4-stroke engine running at 2000 rpm has a carburettor venturi with a 3 cm throat. Determine the suction at the throat assuming the volumetric efficiency of the engine to be 70%. Take air density to be 1.2 kg/m³ and C_D for air = 0.80. **(13 Marks)**

$D_{cyl} = 10\text{ cm}, \quad S = 12\text{ cm}, \quad n_c = 4, \quad n_k = 2$

$N = 2000\text{ rpm}, \quad D_{th} = 3\text{ cm}, \quad \eta_v = 70\%$

$$V_s = \frac{\pi}{4} D_{cyl}^2 S\, n_c$$

$$= \frac{\pi}{4}\left(\frac{10}{100}\right)^2\left(\frac{12}{100}\right) 4 =$$

$$= 0.00377\text{ m}^3 \qquad 3$$

$$\text{Actual } V_s = \eta_{vol} * V_s$$

$$= 0.7 * 0.00377$$

$$= 0.002639\text{ m}^3 \qquad 3$$

Actual mass succed in per unit time

$$= V_s * \rho_a * psps$$

$$= 0.002639 * 1.2 * \frac{2000}{120} \qquad 3$$

$$\dot{m}_a = 0.05278\text{ kg/s}$$

$$= C_D A_2 \sqrt{2 \rho_a \Delta P_a}$$

$$\therefore \Delta P_a = 0.0339\text{ bar} \qquad 4$$