Indian Institute of Technology Kharagpur

Department of Mechanical Engineering

Class Test-1

Internal Combustion Engine

1. The engine of the Fiat car has four cylinders of 68 mm bore and 75 mm stroke. The compression ratio is 8. Calculate the cubic capacity of the engine and the clearance volume of each cylinder. **3**

2. Derive an expression for the dimensionless piston speed. **3**

3. Derive an expression for the dimensionless cylinder volume $V(\theta)/V(0)=f(\theta, r_c, R)$. Here, r_c is compression ratio and $R=r/a$, r= connecting rod length and a is crank radius. **4**

4. Compute the mean piston speed, bmep, torque and power/area for the engine for which $\dot{W}_b$ =1118 kW, B=0.136 m, N=2600 rpm, S=0.127 m, n_c = 12. **4**

5. A 3.8 L four-stroke fuel-injected automobile engine has a power output of 88 kW at 4000 rpm and volumetric efficiency of 0.85. The bsfc is 0.35 kg/kW-hr. If the fuel has a heat of combustion of 42000 kJ/kg, what are the bmep, thermal efficiency, and air to fuel ratio? Assume atmospheric conditions of 298 K and 1 bar. **6**

1. $B = 68\,mm$

$S = 75\,mm$

$$V_d = \frac{\pi}{4}B^2 S = \frac{\pi}{4} \times 6.8^2 \times 7.5 \; cm^3/\text{cylinder}$$

$$= 272.4 \; cm^3/\text{cylinder}.$$

$$r_c = \frac{V_d + V_c}{V_c} = \frac{V_d}{V_c} + 1$$

$$8 = \frac{V_d}{V_c} + 1$$

$$\frac{V_d}{V_c} = 8 - 1 = 7.$$

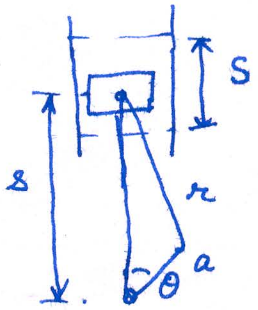
$$V_c = \frac{V_d}{7} = \frac{272.4}{7} = 38.9 \; cm^3/\text{cylinder}.$$

$\therefore$ Cubic capacity of engine $= 272.4 \times 4 \; cm^3 = 1089.6 \; cm^3$

Clearance volume $= 38.9 \; cm^3$.

2. $$s = a\cos\theta + \sqrt{r^2 - a^2\sin^2\theta}$$

$$= a\left[\cos\theta + \sqrt{R^2 - \sin^2\theta}\right] \quad \text{where } R = \frac{r}{a}.$$



$$U_p = \frac{ds}{dt} = a\left[-\sin\theta + \frac{1}{\cancel{2}} \cdot \frac{1}{\sqrt{R^2 - \sin^2\theta}} \cdot (-\cancel{2}\sin\theta\cos\theta)\right]\omega$$

$$= -a\sin\theta\left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right]\omega$$

$$\bar{U}_p = \frac{2SN}{60} \quad \text{where } N = RPM.$$

$$= \frac{2\pi N}{60} \times \frac{1}{\pi} \times S$$

$$= \frac{\omega S}{\pi} \qquad S = 2a$$

$$= \omega \cdot \frac{2a}{\pi}.$$

Non-dimensional piston speed

$$\frac{U_p}{\bar{U}_p} = -\cancel{a}\sin\theta\left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right]\cancel{\omega} \cdot \frac{\pi}{\cancel{\omega} \cdot (2\cancel{a})}$$

$$\boxed{\frac{U_p}{\bar{U}_p} = -\frac{\pi}{2}\sin\theta\left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right]}$$

3. Cylinder volume at any instant of time

$$= V_c + \frac{\pi}{4} B^2 (l + a - s)$$

A_p = Piston area $= \frac{\pi}{4} B^2$

$$= V_c + A_p \left[l + a - \left(a\cos\theta + \sqrt{l^2 - a^2 \sin^2\theta} \right) \right]$$

$$= V_c + A_p . a \left[R + 1 - \left(\cos\theta + \sqrt{R^2 - \sin^2\theta} \right) \right]$$

$$r_c = \frac{V_d + V_c}{V_c} = \frac{V_d}{V_c} + 1$$

$$\frac{V_d}{V_c} = (r_c - 1)$$

$$= V_c + \frac{A_p . S}{2} \left[R + 1 - \left(\cos\theta + \sqrt{R^2 - \sin^2\theta} \right) \right]$$

$$= V_c + \frac{V_d}{2} \left[R + 1 - \left(\cos\theta + \sqrt{R^2 - \sin^2\theta} \right) \right]$$

$$\cancel{= V_c \left[1 + \right.} \quad \frac{V_c}{2} + \frac{V_c}{2}$$

$$= V_c \left[1 + \frac{V_d}{2V_c} \left\{ R + 1 - \left(\cos\theta + \sqrt{R^2 - \sin^2\theta} \right) \right\} \right]$$

$$= V_c \left[1 + \frac{r_c - 1}{2} \left\{ R + 1 - \left(\cos\theta + \sqrt{R^2 - \sin^2\theta} \right) \right\} \right]$$

4. $\dot{W}_b = 1118$ kW, $B = 0.136$ m, $S = 0.127$ m, $N = 2600$ RPM, $n_c = 12$.

$$\bar{U}_p = \frac{2SN}{60} = \frac{2 \times 0.127 \times 2600}{60} \text{ m/s} = 11 \text{ m/s.}$$

$$V_d = \frac{\pi}{4} B^2 S \text{ /cylinder}$$

$$= \frac{\pi}{4} \times 0.136^2 \times 0.127 \text{ m}^3\text{/cylinder}$$

$$= 1.84 \times 10^{-3} \text{ m}^3\text{/cylinder}$$

$$bmep = \frac{\dot{W}_b}{1.84 \times 10^{-3} \times 12 \times \frac{2600}{120}} = \frac{1118}{0.4784} \text{ kPa} = 2337 \text{ kPa.}$$

$$\frac{2\pi N}{60} \times \tau = \dot{W}_b$$

$$\frac{2\pi \times 2600}{60} \times \tau = 1118 \times 10^3$$

$$\tau = 4106 \text{ N-m.}$$

$$\text{Power/area} = \frac{1118}{12} \Big/ \left(\frac{\pi}{4} \times 0.136^2 \right) \frac{\text{kW}}{\text{m}^2}$$

$$= 6413.5 \text{ kW/m}^2$$

5. $\dot{W}_b = 88\,kW$, $V_d = 3.8\,L$, $N = 4000\,RPM$. $\eta_v = 0.85$.

$bsfc = 0.35\,kg/kW\text{-}hr = \dot{m}_f/\dot{W}_b$ where $\dot{m}_f = kg/hr$.
$\dot{W}_b = kW$

$$0.35 = \frac{\dot{m}_f}{88}$$

$$\therefore \dot{m}_f = 0.35 \times 88 \; kg/hr$$

$$= \frac{0.35 \times 88}{3600} \; kg/sec$$

$$= 8.55 \times 10^{-3} \; kg/sec.$$

$$\rho_a = \frac{P_a}{RT} = \frac{10^5}{287 \times 298} \; kg/m^3 = 1.17 \; kg/m^3.$$

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_d \frac{N}{120}} \quad \text{or,} \quad 0.85 = \frac{\dot{m}_a}{1.17 \times 3.8 \times 10^{-3} \times \frac{4000}{120}}$$

$$\therefore \dot{m}_a = 0.126 \; kg/sec.$$

$$\therefore A/F = \frac{0.126}{8.55 \times 10^{-3}} = \underline{14.7}$$

$$bmep = \frac{88 \times 10^3}{3.8 \times 10^{-3} \times \frac{4000}{120}} \; P_a = \underline{695 \; kPa.}$$

COMBUSTION EFFICIENCY 100%

$$\eta_{bth} = \frac{\dot{W}_b}{\dot{m}_f \times Q_{cv}} = \frac{88}{8.55 \times 10^{-3} \times 42000} = \underline{24.5\%}$$