Internal Combustion Engines

Applied Thermo-Fluids I - ME41001

Time: 45 minutes

For Air, molecular mass 28.97 kg/kmole; γ = 1.4; R = 287 J/kg.K

Acceleration due to gravity 9.81 m/sec^2

An SI engine producing 190.9 N-m brake torque at 3000RPM is having bsfc (brake specific fuel consumption) 240 g/kW-hr. The fuel used is gasoline (C_8H_{15}) and the equivalence ratio is 0.833. Consider the flow to be compressible.

(a) Calculate the mass flow rate of fuel and air (in kg/sec).

(b) Derive the necessary equation for air mass flow rate. Calculate the throat diameter of the venturi if the actual air velocity is 120 m/s at the throat. The inlet condition is 101 kPa and 27^{0}C. The discharge coefficient is 0.96 for the venturi.

(c) Derive the necessary equation for fuel flow rate at the capillary jet. Calculate the diameter of the main metering jet (i.e. capillary fuel nozzle) if the tip of the jet is 2.5 mm above the fuel level in the float chamber. Specific gravity of fuel is 0.77. The discharge coefficient is 0.74 for the capillary nozzle.

(2+2)+(4+4)+(4+4)=20

τ = brake torque = 190.9 N-m.

N = 3000 RPM.

$\therefore$ brake power $\dot{W}_b = \frac{2\pi N}{60} \times 190.9$

$= \frac{2 \times \pi \times 3000}{60} \times 190.9$ W

= 60 kW

bsfc = 240 g/kW.hr.

$\therefore$ $\dot{m}_f = 240 \times 60 \ \frac{g}{hr}$

$= 4 \ \frac{g}{sec}$

$= 4 \times 10^{-3}$ kg/sec

Fuel is gasoline C_8H_{15}

C_8H_{15} 1

$$C_8H_{15} + 11.75\,(O_2 + 3.76N_2) \rightarrow 8CO_2 + 7.5\,H_2O + 44.18\ N_2$$

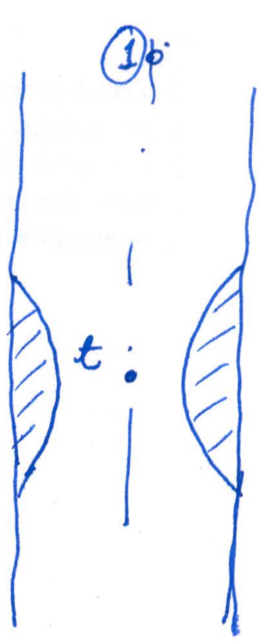
$$(A/F)_{stoich} = \frac{11.75 \times 4.76 \times 28.97}{8 \times 12 + 15 \times 1} = 14.6$$

Equivalence ratio = 0.833

$$\therefore (A/F)_{act} = \frac{14.6}{0.833} = 17.53$$

$\dot{m}_f = 4 \times 10^{-3}$ kg/sec

(a) $\underline{\underline{\dot{m}_a = 0.07012 \text{ kg/sec}}}$



SFEE between 1 and t

$$h_1 + \frac{V_1^2}{2} + gz_1 = h_t + \frac{V_t^2}{2} + gz_2$$

Neglecting V_1 and potential head,

$$h_1 = h_t + \frac{V_t^2}{2}$$

or, $c_p T_1 = c_p T_t + \frac{V_t^2}{2}$

$$c_p T_t = c_p T_1 - \frac{V_t^2}{2}$$

$$T_t = T_1 - \frac{V_t^2}{2c_p} \qquad c_p = 1.005 \text{ kJ/kgK}$$

$$= 300 - \frac{120^2}{2 \times 1005} \qquad T_1 = 300\text{K}$$

$$= 300 - 7.16$$

$$= 292.84$$

$$\dot{m}_a = C_{Dt}\, \rho_t A_t V_t$$

$$0.07012 = 0.96 \times \frac{92.81 \times 10^3}{287 \times 292.84} \times A_t \times 120$$

$$A_t = \frac{0.07012 \times 287 \times 292.84}{0.96 \times 92.81 \times 120 \times 10^3}$$

$$= 0.551 \times 10^{-3}\ m^2$$

$$\frac{\pi}{4} d_t^2 = 0.551 \times 10^{-3}\ m^2$$

(b) $d_t =$ ~~83.8 cm~~ 2.35 cm

$$\rho_t = \frac{P_t}{RT_t}$$

$$\left(\frac{P_t}{P_0}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_t}{T_0}$$

$$\frac{P_t}{P_0} = \left(\frac{T_t}{T_0}\right)^{\frac{\gamma}{\gamma-1}}$$

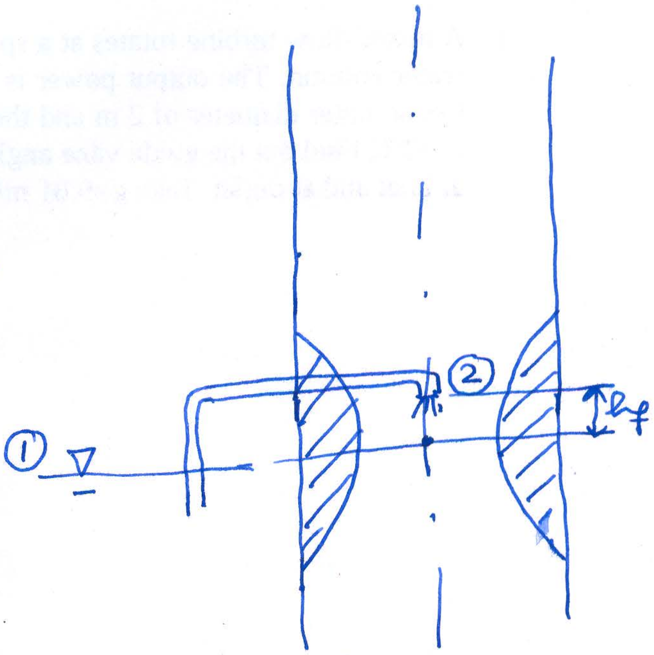
$$P_t = 101 \times \left(\frac{292.84}{300}\right)^{\frac{1.4}{1.4-1}}$$

$$= 0.919 \times 101$$

$$= 92.81 \text{ kPa}$$

For fuel

Bernoulli's equation from 1 to 2



$$\cancel{p=}\ \frac{P_1}{\rho}+\frac{V_1^2}{2}+gZ_1=\frac{P_2}{\rho}+\frac{V_2^2}{2}+gZ_2$$

$$V_1 \simeq 0$$

$$\frac{V_2^2}{2}=\frac{P_1-P_2}{\rho}-gh_f$$

$$V_2=\sqrt{\frac{2[(P_1-P_2)-\rho g h_f]}{\rho}}$$

$$=\sqrt{\frac{2\times\left[(101-92.81)\times10^3-770\times 9.81\times\frac{2.5}{1000}\right]}{770}}$$

$\rho = 0.77\times1000\ kg/m^3 = 770\ kg/m^3$

$$=4.6\ m/s$$

$$\dot{m}_f = C_{Dc}\times\rho\times A_c\times V_2$$

$$4\times10^{-3}=0.74\times770\times A_c\times4.6$$

$$A_c = 1.526\times10^{-6}\ m^2$$

$$d_c = 1.39\times10^{-3}\ m$$

(c) $\underline{\underline{d_c = 1.39\ mm}}$