Internal Combustion Engines

Lecture-6

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Example#1

A simple jet carburetor is required to supply 5 kg of air and 0.5 kg of fuel per minute. The fuel specific gravity is 0.75. The air is initially at 1 bar and 300 K. Calculate the throat diameter of the choke for a flow velocity of 100 m/s. Velocity coefficient is 0.8. If the pressure drop across the fuel metering orifice is 0.80 of that of the choke, calculate orifice diameter assuming, $C_{df} = 0.60$ and $\gamma = 1.4$.

Solution:

Velocity at throat, C_2

$$C_2 = V_c\sqrt{2C_pT_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

$$100 = 0.8\times\sqrt{2\times 1005\times 300\times\left[1-\left(\frac{p_2}{p_1}\right)^{0.286}\right]}$$

$$\left(\frac{p_2}{p_1}\right)^{0.286} = 1-\left(\frac{100}{0.8}\right)^2\times\frac{1}{2\times 1005\times 300} = 0.974$$

$$\frac{p_2}{p_1} = (0.974)^{1/0.286} = 0.912$$

$$p_2 = 0.912 \text{ bar}$$

$$v_1 = \frac{RT_1}{p_1} = \frac{0.287 \times 300}{10^5} \times 1000$$

$$= 0.861 \text{ m}^3$$

$$p_1 v_1^\gamma = p_2 v_2^\gamma$$

$$v_2 = v_1 \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma}} = 0.861 \times \left(\frac{1}{0.912}\right)^{0.714}$$

$$= 0.919 \text{ m}^3/\text{kg}$$

Throat area,

$$A_2 = \frac{\dot{m}_a \times v_2}{C_2} = \frac{5}{60} \times \frac{0.919}{100} \times 10^4$$

$$= 7.658\ \text{cm}^2$$

$$d_2 = \sqrt{7.658 \times \frac{4}{\pi}} = 3.12\ \text{cm}$$

$$\Delta p_a = 1 - 0.912 = 0.088$$

$$\Delta p_f = 0.80 \times 0.088 = 0.07\ \text{bar}$$

$$\dot{m}_f = A_f C_f \sqrt{2\rho_f \Delta p_f}$$

$$\frac{0.5}{60} = A_f \times 0.6 \times \sqrt{2 \times 750 \times 0.07 \times 10^5}$$

$$A_f = \frac{0.5 \times 10^4}{60 \times 0.6 \times 3.24 \times 10^3} = 0.0428\ \text{cm}^2$$

$$d_f = \mathbf{2.34\ mm}$$

Example#2

A four-cylinder, four-stroke square engine running at 40 rev/s has a carburetor venturi with a 3 cm throat. Assuming the bore to be 10 cm, volumetric efficiency of 75%, the density of air to be 1.15 and coefficient of air flow to be 0.75. Calculate the suction at the throat.

Solution:

$$\text{Swept volume, } V_s = \frac{\pi}{4} \times 10^2 \times 10 \times 10^{-6} \times 4$$

$$= 0.00314 \text{ m}^3$$

$$\text{Volume sucked/s} = \eta_v \times V_s \times n$$

$$= 0.75 \times 0.00314 \times \frac{40}{2}$$

$$= 0.047 \text{ m}^3/\text{s}$$

$$\dot{m}_a = 0.047 \times 1.15 = 0.054 \text{ kg/s}$$

Since the initial temperature and pressure is not given, the problem is solved by neglecting compressibility of the air

$$\dot{m}_a = C_d A_2 \sqrt{2\rho_a \Delta p_a}$$

$$\Delta p_a = \left(\frac{\dot{m}_a}{C_d A_2}\right)^2 \frac{1}{2\rho_a}$$

$$= \left(\frac{0.054}{0.75 \times \frac{\pi}{4} \times (0.03)^2}\right)^2 \times \frac{1}{2 \times 1.15}$$

$$= 4510.99 \text{ N/m}^2$$

$$= 0.0451 \text{ bar}$$

Ans

Example#3

The venturi of a simple carburetor has a throat diameter of 20 mm and the coefficient of flow is 0.8. The fuel orifice has a diameter of 1.14 mm and the coefficient of fuel flow is 0.65. The gasoline surface is 5 mm below the throat, calculate

(i) the air-fuel ratio for a pressure drop of 0.08 bar when the nozzle tip is neglected

(ii) the air-fuel ratio when the nozzle tip is taken into account

(iii) the minimum velocity of air or critical air velocity required to start the fuel flow when the nozzle tip is provided. Assume the density of air and fuel to be 1.20 kg/m^3 and 750 kg/m^3 respectively.

Solution

(i) When the nozzle tip is neglected

$$\dot{m}_a = C_{da} A_a \sqrt{2\rho_a \Delta p}$$

$$\dot{m}_f = C_{df} A_f \sqrt{2\rho_f \Delta p}$$

$$A/F = \frac{C_{da}}{C_{df}} \frac{A_a}{A_f} \sqrt{\frac{\rho_a}{\rho_f}}$$

$$= \frac{0.80}{0.65} \times \left(\frac{20}{1.14}\right)^2 \times \sqrt{\frac{1.20}{750}} = \mathbf{15.15}$$

(ii) When the nozzle tip is taken into account

$\dot{m}_a$ will remain the same. But

$$\dot{m}_f = C_{df} A_F \sqrt{2\rho_f(\Delta p - \rho_f g h_f)}$$

$$\rho_f g h_f = \frac{5}{1000} \times 9.81 \times 750 = 36.79 \text{ N/m}^2$$

$$= 36.79 \times 10^{-5} = 0.00037 \text{ bar}$$

$$\Delta p - \rho_f g h_f = 0.08 - 0.00037 = 0.0796 \text{ bar}$$

$$A/F = \frac{C_{da}}{C_{df}} \frac{A_a}{A_f} \sqrt{\frac{\rho_a}{\rho_f}} \sqrt{\frac{\Delta p}{\Delta p - \rho_f g h_f}}$$

$$= \frac{0.8}{0.65} \times \left(\frac{20}{1.14}\right)^2 \times \sqrt{\frac{1.2}{750}} \times \sqrt{\frac{0.08}{0.0796}}$$

$$= \mathbf{15.19}$$ Ans ⇐

When there is a nozzle tip, the fuel flow will start, only when the minimum velocity of air required to create the requisite pressure difference for the flow of fuel to overcome nozzle tip effect. The pressure difference Δp must be equal to $\rho_f g h_f$. Assuming velocity at the entrance of venturi $C_1 = 0$, we have

$$\frac{p_1}{\rho_a} = \frac{p_2}{\rho_a} + \frac{C_2^2}{2}$$

$$\frac{\Delta p}{\rho_a} = \frac{C_2^2}{2} = \frac{\rho_f g h_f}{\rho_a}$$

$$C_{min} = \sqrt{2 g h_f \frac{\rho_f}{\rho_a}} = \sqrt{2 \times 9.81 \times \frac{5}{1000} \times \frac{750}{1.2}}$$

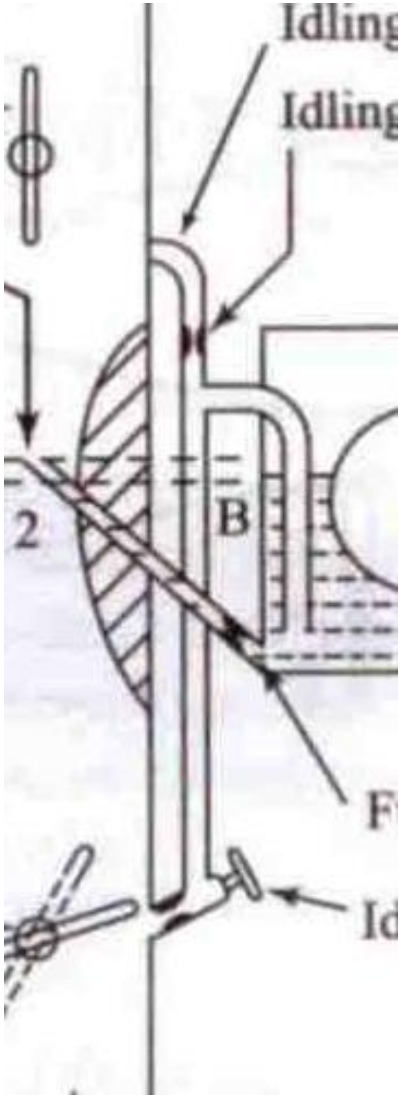
$$= \mathbf{7.83\ m/s}$$

Ans ⟸

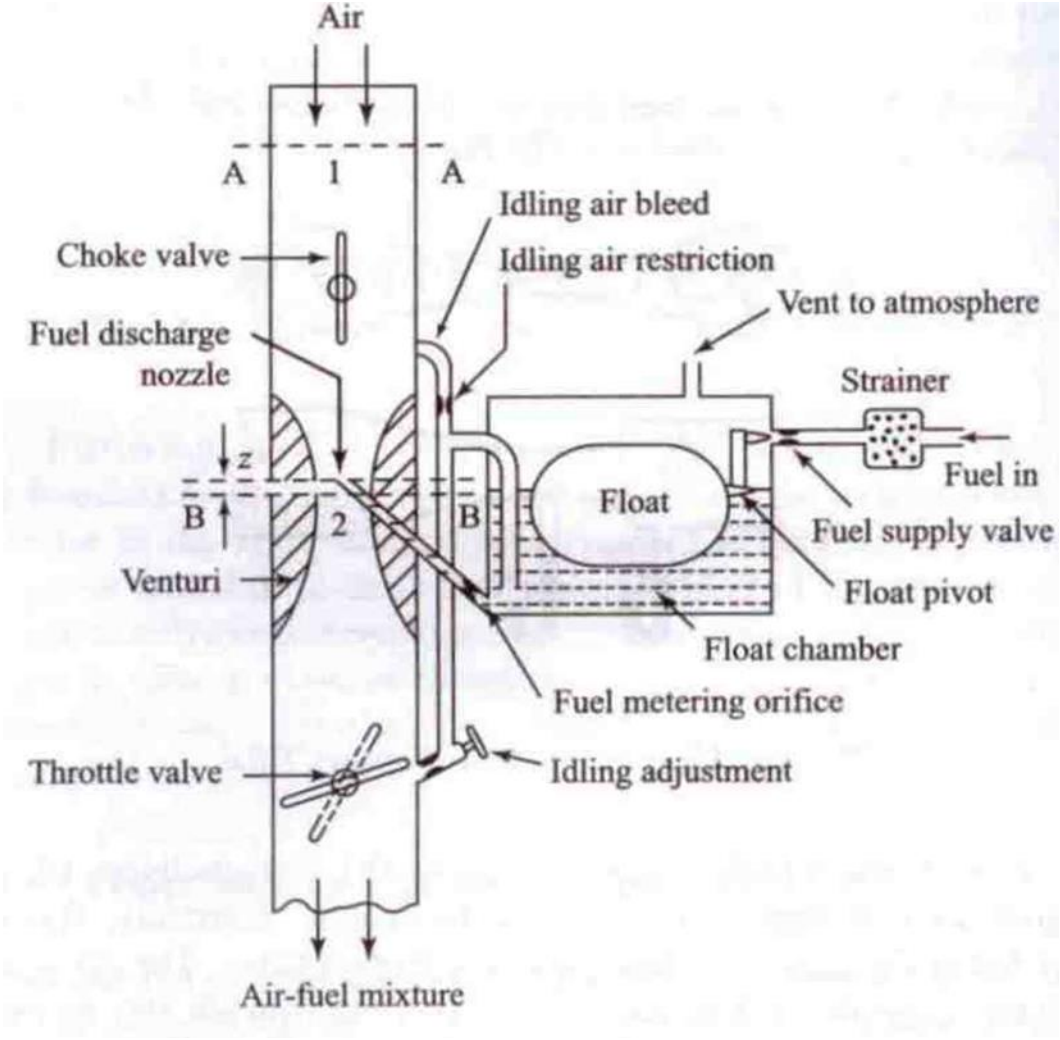
The nozzle tip is the height of fuel nozzle in the throat above the gasoline surface in the carburetor. This is provided to avoid spilling of fuel due to vibration or slight inclination position of the carburetor. This would avoid wastage of fuel.

Idling Jet

- This is required to supply the increased F/A during idling
- A narrow tube connects downstream of throttle to atmospheric condition
- At low throttle opening, pressure at the downstream of throttle is very low
- The idling line is active then and air flow through it
- Due to pressure drop, fuel from tank is discharged in the idling line
- Idling adjustment screw is there to regulate the fuel flow
- At lower throttle, air flow is very small
- The fuel through main line is even smaller to maintain theoretical F/A (near stoichiometric)

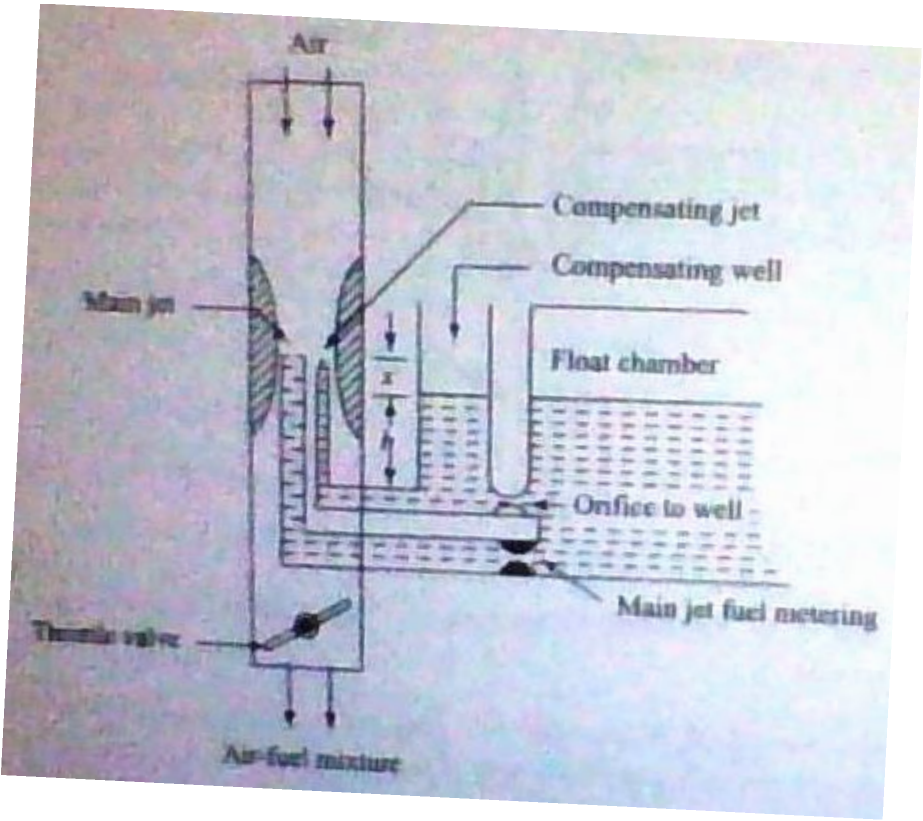


Carburetor Schematic



- Choke is normally open
- It needs to be operated for cold starting
- Choke closing creates depression at downstream and so the fuel flow increases

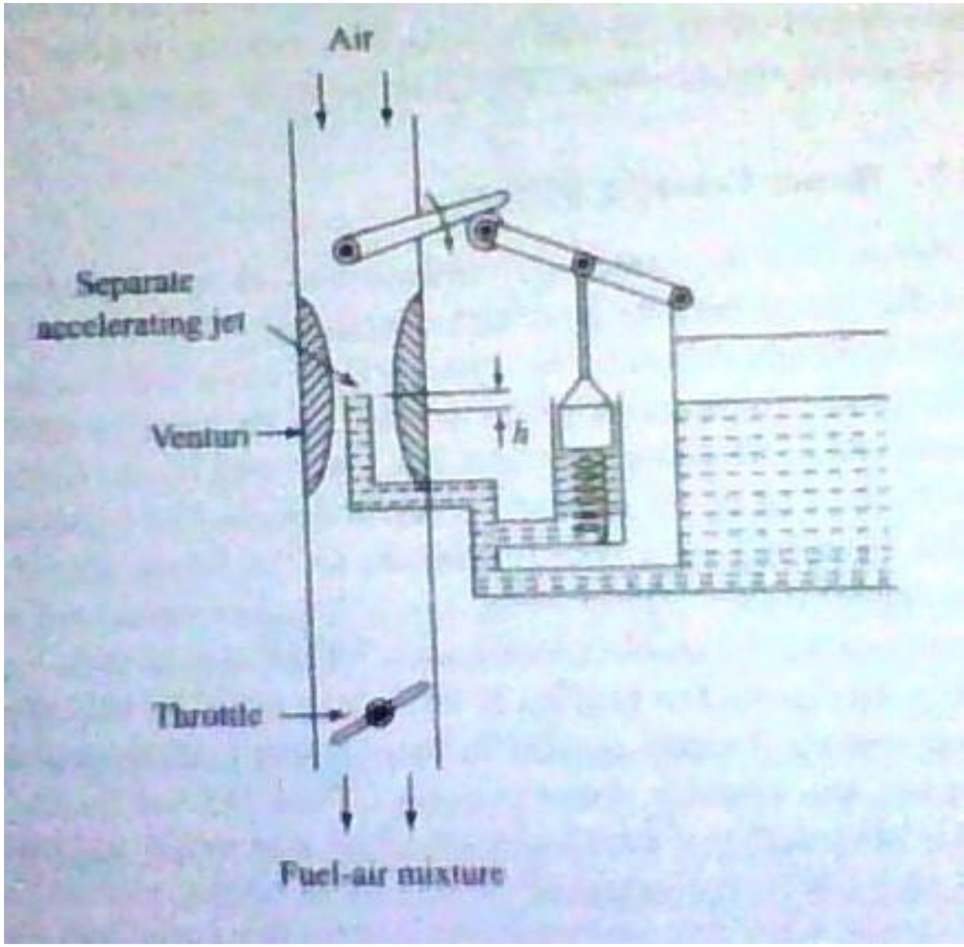
Compensating Jet Device



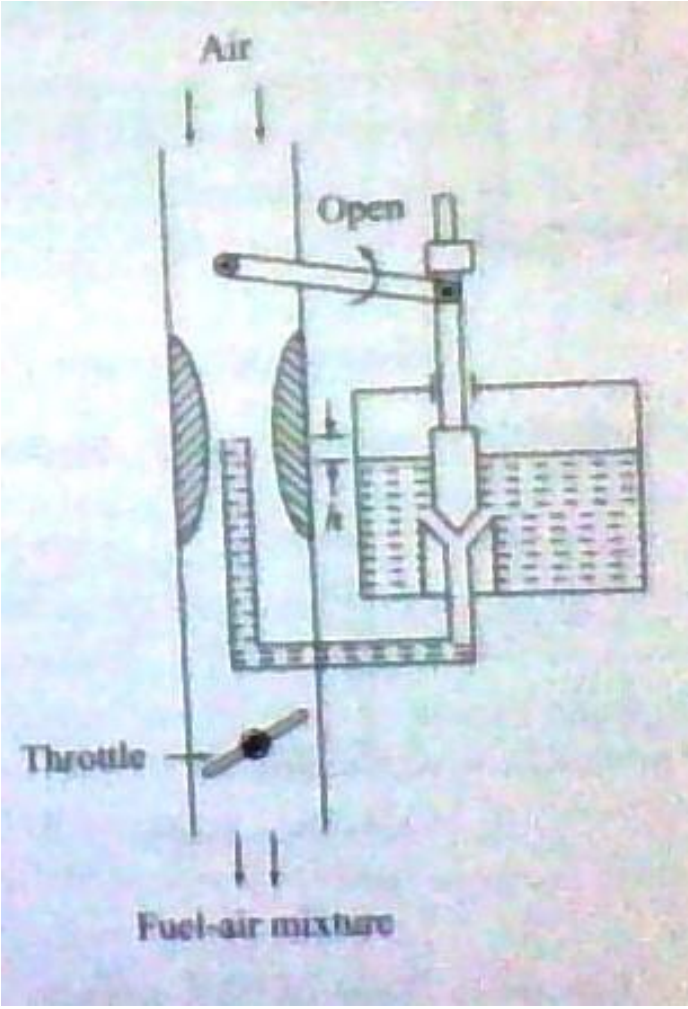
- F/A increases with increases in throttle opening with simple carburetor
- This variation is compensated using this device
- The compensating jet is connected to a fuel chamber, in which fuel level depletes at higher throttle opening
- So, with throttle opening fuel flow decreases

Accelerating Pump

- Required for sudden acceleration
- Sudden acceleration creates momentary decrease in F/A
- Because air reacts quick as on primary control is on air line. Fuel flow is sluggish due to on secondary path
- This pump supplies extra fuel during sudden acceleration to maintain F/A ratio



Economiser/Power Enrichment System



- This is employed to cater to the need of richer F/A in power zone
- A valve constricts the passage of fuel flow in main duct in idling and cruising zones
- During power zone the constriction is gradually released as shown and fuel flow increases, thus F/A ratio

Thank You