Internal Combustion Engines

Carburetor

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Carburetion

- The process of mixture preparation in an SI engine is called carburetion. This air-fuel mixture is prepared outside the cylinder in a device called CARBURETOR.

- The carburetor atomizes the fuel and mixes with air in different proportions for various LOAD conditions.

**Loads**
- Starting
- Idling
- Cruising
- Accelerating
Petrol & Diesel Engines
Functions

- It must atomize, vaporize and mix the fuel homogeneously with air.

- It must supply correct amount of air-fuel mixture in correct proportion under all load conditions and speed of the engine.

- It must run the engine smoothly by supplying a correct mixture strength.
Factors affecting Carburetion

- the time available for mixture preparation
- the temperature of the incoming air
- the quality of the fuel supplied
- the engine speed
- the design of the carburetor
Remark

- For high speed engines (3000 rpm), the time available for mixture preparation is very small (0.02 sec).

- The temperature affects the vaporization of fuel. High temperature leads to high rate of vaporization. This is achieved by heating the induction manifold in some cases. However, this causes a reduction in the power output because of decrease in mass flow rate.

- The design of carburetor, as such, is very complicated because the optimum air-fuel ratio varies over its operating range.
Air-Fuel Mixtures

- **Chemically Correct (15:1)**
- **Rich Mixture (10:1)**
- **Lean Mixture (17:1)**

![Diagram showing air-fuel ratio and mixture types]
Variation of power output and sfc with A-F ratio in SI engine (Full throttle and constant speed)

- **Maximum Output** = 12:1 *(Best power mixture)*
- **Minimum Fuel Consumption** = 16:1 *(Best economy mixture)*
Various Loads

- **Idling/Starting**: Engine runs without load. Produces power only to overcome friction between the parts. *Rich mixture* is required to sustain combustion.

- **Normal Power/Cruising/Medium Load**: Engine runs for most of the period. Therefore, fuel economy is maintained. Low fuel consumption for maximum economy. *Requires a lean mixture.*

- **Maximum power/Acceleration**: Overtaking a vehicle (short period) or climbing up a hill (extra load). *Requires a rich mixture.*
Starting a Cold Engine

- When an engine is cold, a very small % fuel will vaporize in the intake and compression process. The fuel is also cold, and much more viscous, creating a lower flow rate. The engine metal parts are cold and inhibit vaporization. Further, during the compression stroke, cold cylinder walls will absorb heat and reduce vaporization. Engine lubrication is cold and more viscous, making the engine turn more slowly in the starting process.
Simple Carburetor

- Inlet Valve
- Throttle
- Fuel discharge nozzle
- Fuel metering jet lip, $h$
- Choke
- Vent
- Fuel from supply
- Float Chamber
- Air
- Fuel supply

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Components of a Simple Carburetor

- A float chamber with a float to store fuel and to adjust its level
- A round cylinder with a venturi for atomization of fuel.
- A fuel nozzle to atomize and produce a spray of fuel
- A throttle valve to supply varying quantity of the mixture at different load conditions
- A choke valve to control the air supply in order to provide a rich or a lean mixture
Venturi-type Carburetor

Bernoulli Effect:
P + 1/2 ρV^2 = Constant

Fuel Inlet
Float
Bowl

Valve Stem

Venturi
Throttle Plate
Atomized Fuel

Choke Plate
Fuel Nozzle
Inlet Air

Air/Fuel Mixture To Engine

Metering Orifice
The fuel supply to the float chamber is controlled by the action of the float and the attached fuel supply valve. During the intake or the suction stroke of the engine, the piston moves from TDC to BDC, and creates a vacuum in the space above it and in the suction manifold. Due to this fall in pressure, the atmospheric air rushes into the carburetor. Near the venturi, velocity increases, pressure decreases and the fuel comes out in the form of a jet. The fuel gets mixed with air and goes into the cylinder.
Because of the narrow passage at the venturi throat, the air velocity increases but its pressure falls. This causes a partial vacuum (called carburetor depression) at the venturi throat. This carburetor depression causes fuel to come out as jet in the form of a spray. This fuel spray vaporizes and mixes with the incoming air, and the mixture goes into the cylinder through the throttle valve.
A simple carburetor as described suffers from the fact that it provides the required air-fuel ratio only at one throttle position.

At all other throttle positions, the mixture is either leaner or richer depending on whether the throttle is opened less or more.
Drawback of Simple Carburetor

- Throttle opening changes the velocity of air. The opening changes the pressure differential between the float chamber and venturi throat, and regulates the fuel flow through the nozzle.

- Increased throttle opening gives a rich mixture. Opening of throttle usually increases engine speed. However, as load is also a factor (e.g., climbing an uphill), opening the throttle may not increase the speed.
Calculation of Air-Fuel Ratio

i.e., we need to calculate

\[ \frac{A}{F} = \frac{m_a}{m_f} \]

- Let the tip of the fuel nozzle be at a height \( z \) from fuel level in the float chamber.
Applying SFEE between A-A (point 1) and B-B (point 2) and considering unit mass of airflow

\[ q - w = h_2 - h_1 + \frac{1}{2} (c_2^2 - c_1^2) \]

For adiabatic flow,

\[ q = 0, \ w = 0, \text{ and } c_1 \approx 0 \]

We have,

\[ c_2 = \sqrt{2(h_1 - h_2)} \]

\[ c_2 = \sqrt{\frac{2C}{p} (T_1 - T_2)} \]
Since mass flow is constant

\[ \dot{m}_a = \rho_1 A_1 C_1 = \rho_2 A_2 C_2 \]

Also,

\[ p_1 v_1^k = p_2 v_2^k \]
\[ \frac{v_1^k}{v_2^k} = \frac{p_2}{p_1} \]

We have

\[ \therefore v_2 = v_1 \left( \frac{p_1}{p_2} \right)^{\frac{1}{k}} \]
\[ v_2 = \frac{RT_1}{p_1} \left( \frac{p_1}{p_2} \right)^{\frac{1}{k}} \]
\[ \dot{m}_a = \frac{A_2 C_2}{v_2} \text{ gives} \]

\[ \dot{m}_a = \frac{A_2}{RT_1 \left( \frac{p_1}{p_2} \right)^{1/k}} \sqrt{2C p T_1 \left[ 1 - \left( \frac{p_2}{p_1} \right)^{k-1/k} \right]} \]

Finally, we have

\[ (\dot{m}_a)_{\text{theoretical}} = \frac{A_2 p_1}{R \sqrt{T_1}} \sqrt{2C p \left[ \left( \frac{p_2}{p_1} \right)^{2/k} - \left( \frac{p_2}{p_1} \right)^{k+1/k} \right]} \]

\[ (\dot{m}_a)_{\text{actual}} = C_{d_t} (\dot{m}_a)_{\text{theoretical}} \]

where \( C_{d_t} = \text{coefficient of discharge of venturi throat} \)
To find mass flow rate of fuel

Assuming fuel to be incompressible, we have from Bernoulli’s theorem

\[
\frac{p_1}{\gamma} = \frac{p_2}{\gamma} + \frac{C_f^2}{2g} + z
\]

\[
\therefore \frac{p_1}{\rho_f} - \frac{p_2}{\rho_f} = \frac{C_f^2}{2} + gz
\]

\[
\therefore C_f = \sqrt{2 \left(\frac{p_1 - p_2}{\rho_f} - gz\right)}
\]

\(\rho_f\) being the density of fuel, \(C_f\) is the fuel velocity at the nozzle exit and \(z\) is the nozzle lip.
Thus, we have velocity of fuel at the nozzle exit

\[ \therefore C_f = \sqrt{2 \left( \frac{p_1 - p_2}{\rho_f} - gz \right)} \]

\[ \therefore (\dot{m}_f)_{\text{theoretical}} = \rho_f A_f C_f \]

\[ \therefore (\dot{m}_f)_{\text{theoretical}} = A_f \sqrt{2 \rho_f (p_1 - p_2 - \rho_f gz)} \]

\[ \therefore (\dot{m}_f)_{\text{actual}} = C_{d_f} (\dot{m}_f)_{\text{theoretical}} \]

where \( C_{d_f} \) = coefficient of discharge of fuel nozzle
A simple carburetor is capable to supply a correct air-fuel mixture to the engine only at a particular load and speed. In order to meet the engine demand at various operating conditions, the following additional systems are added to the simple carburetor.

- idling system
- auxiliary port system
- power enrichment by economizer system
- accelerating pump system
- choke
During starting or idling, engine runs without load and the throttle valve remains in closed position. Engine produces power only to overcome friction between the parts, and a rich mixture is to be fed to the engine to sustain combustion.
The idling system as shown consists of an idling fuel passage and an idling port. When the throttle is partially closed, a depression past the throttle allows the fuel to go into the intake through the idle tube. The depression also draws air through the idle air bleed and mixes with fuel. The fuel flow depends on the location of the idle nozzle and the adjustment of the idle screw.
During normal power or cruising operation, where the engine runs for most of the period, the fuel economy has to be maintained. Thus, it is necessary to have lower fuel consumption for maximum economy. One such arrangement used is the auxiliary port carburetor as shown, where opening of butterfly valve allows additional air to be admitted, and at the same time depression at the venturi throat gets reduced, thereby decreasing the fuel flow rate.
In order to obtain maximum power, the carburetor must supply a rich mixture. This additional fuel required is supplied by a power enrichment system that contains a meter rod economizer that provides a larger orifice opening to the main jet as the throttle is opened beyond a certain point.
During sudden acceleration of an engine (e.g., overtaking a vehicle), an extra amount of fuel is momentarily required to supply a rich mixture. This is obtained by an accelerating pump system. It consists of a spring-loaded plunger, and the necessary linkage mechanism.

The rapid opening of the throttle moves the plunger into the cylinder, and an additional amount of fuel is forced into the venturi.
During cold starting period, at low cranking speed and before the engine gets warmed up, a rich mixture has to be supplied, simply because a large fraction of the fuel remains in liquid state in the cylinder, and only the vapor fraction forms the combustible mixture with air. The most common method of obtaining this rich mixture is to use a choke valve between the entry to the carburetor and the venturi throat.
Types of Carburetor based on direction of flow

- Up-draught (updraft) carburetor
- Down-draught (downdraft) carburetor
- Cross-draught or horizontal carburetor
A single barrel carburetor has one outlet connected to the intake manifold of engine.

A multi-barrel barrel carburetor is one with two outlets connected to two intake manifolds of engine. Such unit is basically one with two carburetors.

As such, a multi-barrel barrel carburetor has two numbers of idling, power and accelerating systems, two chokes, two throttles but with alternate cylinders in the firing order. As for example, in a six cylinder engine, one barrel supplies mixture to cylinders 1, 3 and 2; while the other barrel supplies to 5, 6 and 4.
Automobile carburetors are calibrated at sea-level conditions.

- Lower altitudes (than sea-level): Lean mixture
- Higher altitudes (than sea-level): Rich mixture (emits hydrocarbon, CO)

At higher altitudes, density decreases and hence, the mass flow rate gets reduced.
Enrichment (due to variation of air density)

\[
E + 1 = \sqrt{\frac{\rho_0}{\rho}}
\]

\[
E + 1 = \sqrt{\frac{p_0RT}{RT_0p}}
\]

\[
E + 1 = \sqrt{\frac{p_0T}{pT_0}}
\]

If \( \frac{\rho}{\rho_0} = 0.84 \),

\[
E + 1 = \sqrt{\frac{1}{0.84}} = 1.091
\]

\[
E = 0.091 = 9.1\%
\]

*Enrichment of mixture over the calibrated ratio*
Altitude Compensation Device

- As density decreases, the mass flow rate also decreases and hence the Power gets reduced.
- Admit more air and less fuel into the induction manifold.

METHODS

- Reduction of pressure in float chamber
- Auxiliary air valve/air port
- Supercharger
Summary

1. The carburetor is a device which mixes air and fuel in a reciprocating internal combustion engine. Carburetors are still found in small engines and in older or specialized automobiles such as racing cars. However, most cars built since the early 1980s use fuel injection instead of carburetion.
Summary

2. Most carbureted (as opposed to fuel injected) engines have a single carburetor, though some, primarily higher performance engines, can have multiple carburetors. Most automotive carburetors are either downdraft (flow of air is downwards) or side-draft (flow of air is sideways). In the United States, downdraft carburetors were almost ubiquitous, partly because a downdraft unit is ideal for V engines. In Europe, side-draft carburetors are much more common in performance applications. Small propeller-driven flat airplane engines have the carburetor below the engine (updraft).
References

Web Resources

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