Introduction

- SI engines are fed with fuel (normal gasoline, methyl or ethyl alcohol etc.), which is sufficiently volatile and has ignition properties which allow it to be premixed with the combustion air before the combustion is initiated by the spark plug.
- In SI engine, the liquid fuel and the air (which contains necessary oxygen) are mixed prior to arrival in the combustion chamber.
- So, in SI engines, when the fuel is pre-mixed with the air, it is necessary to control the airflow and therefore, indirectly the air-fuel mixture.
- In Diesel engines, the fuel is less volatile and air is only mixed inside the combustion chamber, where the pressure and temperature conditions are such to induce natural ignition.
- So, the power delivery of diesel engines may be adjusted by fuel delivery alone, without the need to control the airflow.
Introduction
The air/fuel mixture can be prepared by either a carburetor or a fuel injection system. In both cases fuel will be present in the inlet manifold as vapor, liquid droplets and a liquid film

Carburetor:
- Patented by Karl Benz in 1886. Two main types:
  - Fixed jet (or fixed venturi)
  - Variable jet (or variable venturi)

Fuel Injection System
- For SI Engines:
  - Single point fuel injection
  - Multi-point fuel injection
- For CI Engines:
  - Pump-line-injector
  - In-line pump
  - Rotary pump
  - Electronic Unit injection
  - Common Rail Direct Injection

Carburetor
- Gasoline must be vaporized and mixed with air in the proper proportions for varying conditions.
- The process of producing a mixture of air and fuel in the correct proportion for engine combustion is called carburation.
- A carburetor is a device that blends air and fuel for an internal combustion engine.
Induction system

- Induction system is responsible for preparing correct air-fuel mixture and directing this mixture to each of the cylinder.
- Carburetor is main part of induction system.
- Liquid fuel supplied to carburetor from the fuel system.
- Air is drawn into carburetor form atmosphere by the action of the engine piston on intake stroke most of the automobile engine induct air directly into carburetor through air cleaner.
- Through **Intake manifold** fuel and air mixture travels from carburetor to the cylinder.
- The **throttle** located in the carburetor regulates the quantity of mixture entering the cylinder.

![Diagram of induction system](image)

Induction system

- During the suction stroke, vacuum created in the cylinder causes the inlet air to flow through the carburetor and fuel is sprayed from the fuel jets in the inlet air stream.
- Most of the fuel vaporizes and forms a combustible fuel-air mixture because of high volatility of fuel.
- **Important factor affecting the process of carburetion are:**
  1. Time available for preparation of mixture.
  2. Temperature of the incoming air.
  3. Quality of fuel supplied.
  4. Design of induction system and combustion chamber.
Chemically correct air/fuel ratio

- A chemical equation for combustion hydrocarbon can be written as follows:
  \[ C_8H_{18} + 12.5 \, (O_2 + 3.76 \, N_2) = 8 \, CO_2 + 9 \, H_2O + 47N_2 \]
- From this, we can calculate for complete combustion, there must be 14.7 kg of air required for every kg of \( C_8H_{18} \) fuel.
- The air/fuel ratio (A/F) in this case is 14.7 : 1
- The quantity of fuel calculated by this method is an ideal amount necessary to react completely with all the oxygen present in the air. Therefore this A/F ratio is known as chemically correct or stoichiometric A/F ratio for this fuel.
- The chemically correct A/F mixture is not a mandatory condition for engine operation.

![Diagram showing practical and ignition limits for hydrocarbons and engine operation](image)

Theoretical considerations

- Carburetor must fulfill following functions:
  1. Meter the liquid fuel in correct quantity to produce A/F ratio required to cater to all engine operating conditions.
  2. Atomize the fuel, and mix it homogeneously with the air.
- Carburetor must be designed to provide as nearly as possible A/F ratio, which the engine requires.
  - The mixture corresponding to the maximum point on the BHP curve is called **best power mixture**.
  - The mixture corresponding to the minimum point on the BSFC curve is called the best **economy mixture**.

- The above figure is based on full throttle operation (WOT).
- The best power mixture is richer than the chemically correct mixture and the best economy mixture is leaner than the chemically correct.
Theoretical considerations

- The A/F ratios for best power and best economy at part throttle are not strictly the same as full load.
- Carburetor could be set for the best power mixture, when maximum performance desired and for best economy mixture, when fuel economy is the primary consideration.
- There are three general ranges of throttle operation. In each of these, engine has different requirements:
  1. Idling (mixture must be enriched)
  2. Cruising (mixture must be lean)
  3. High power (mixture must be enriched)

- The carburetor must modify the A/F ratio to satisfy these demands.

Mixture requirement for minimum SFC

- Maximum efficiency occurs at A/F ratio of ~17:1 (0.06 :1 F/A ratio)
- Maximum efficiency occurs at a point slightly leaner than chemically correct A/F ratio because mixing is not perfect, excess air requires for complete combustion of fuel.

(For various throttle position)
Simple carburetor

The simple carburetor mainly consists of
1. Float chamber,
2. Fuel discharge nozzle
3. Metering orifice
4. Venturi
5. Throttle valve
6. Choke.

Components of a carburetor

- **FLOAT CHAMBER**
  1. The float and a needle valve system maintain a constant level of gasoline in the float chamber
  2. Float chamber is vented either to the atmosphere or to the upstream side of the venturi

- **VENTURI**
  1. A tube of decreasing cross-section with a minimum area at the throat, and is so shaped that it offers minimum resistance to the air flow.
  2. As the air passes through the venturi the velocity increases reaching a maximum at the venturi throat. Correspondingly, the pressure decreases reaching a minimum.
  3. From the float chamber, the fuel is fed to a discharge jet, the tip of which is located in the throat of the venturi
  4. Because of the differential pressure between the float chamber and the throat of the venturi, known as carburetor depression, fuel is discharged into the air stream
Components of a carburetor

- **CHOKE VALVE**
  1. A choke valve controls air supply, in order to provide rich or lean fuel-air mixture.
  2. When the choke is partly closed, large pressure drop occurs at the venturi, which inducts large amount of fuel from the main nozzle and provides a very rich mixture.

- **THROTTLE VALVE**
  1. A throttle valve supplies varying quantity of mixture at different load conditions.

- **FUEL NOZZLE**
  1. It is used to atomize and produce a spray of fuel in the throat.

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Calculation of A/F ratio from simple carburetor

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The fuel supply to the float chamber is controlled by the action of the float and the attached fuel supply valve.

During the intake stroke of the engine, the piston moves from TDC to BDC, and creates a vacuum in suction manifold.

Due to fall in the pressure, the atmospheric air rushes into carburetor.

Near the venturi, the velocity increases, pressure decreases and the fuel oozes out in the form of a jet.

The fuel gets mixed with air and is then inducted into the cylinder.

Because of the narrow passage at the venturi throat, the air velocity increases and its pressure falls. This is known as 'carburetor depression' at venturi throat.

This 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.
Engine A/F mixture requirement

1. IDLE MIXTURE
   - Engine produces power only to overcome friction, and a rich mixture is required by the engine to sustain combustion.
   - When intake valve opens, the pressure differential between combustion chamber and the intake manifold results in backward initial flow of exhaust gases into intake manifold.
   - As the piston moves down on the intake stroke, these exhaust gases are drawn back into the cylinder along with fresh charge
   - It is required to provide more fuel which increases the contact between fuel and air, thus improving combustion.

Idling system

- The idling system consists of an idling fuel passage and 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.
2. CRUISING RANGE

- Normal power or cruising operation require lower fuel consumption for maximum economy.
- The arrangement used is the auxiliary port carburetor where opening of a 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.

3. POWER RANGE

- Richer mixture required for following reasons:
  a) Provide best power output
  b) Prevent overheating of exhaust valve by enriching the mixture, which reduces the flame temperature and cylinder temperature
  c) Inhibit detonation in aircraft engines by enriching the mixture beyond chemically correct, which reduces the flame temperature therefore it reduces possibility of detonation.
- In automobile engines, detonation is produced in the form of audible knock or ping.
- Also the automobile engines operate well below full power therefore enriching fuel-air mixture will not be economical.
- For aircraft engine installations, enriching the mixture is justified and necessary to increase permissible take off power.
POWER ENRICHMENT SYSTEM
- For rich mixtures, additional fuel is supplied by a power enrichment system.
- It consists of a meter rod economizer that provides a larger orifice opening to the main jet as the throttle is opened beyond a certain point.

ACCELERATING PUMP SYSTEM
- During sudden acceleration of an engine, an extra amount of fuel is momentarily required to supply a rich mixture.
- This is obtained by accelerating pump system consists of a spring-loaded plunger and necessary linkage mechanisms.

Transient mixture requirements
- Carburetor has to provide suitable mixture for transient conditions where speed, load, temperature, and pressure change rapidly.
- The principle transition conditions of operation are
  1. Starting
  2. Warming up
  3. Acceleration
  4. Deceleration
- The difference between steady state and transient state are:
  1. Incomplete evaporation
  2. Fluctuation in quantity of liquid fuel in inlet manifold (increasing or decreasing)
  3. Distribution of fuel to various cylinders.
1. **Starting and warm up**

- While starting from cold, the speed as well as engine temperature are low, hence fuel supplied by carburetor does not vaporize and remain in liquid form.
- The vaporized fuel may re-condense upon coming in contact with cold cylinder walls and piston head.
- Hence during start-up, 5 to 10 times the normal amount fuel must be supplied for proper combustion.
- As engine warms up the amount of evaporated fuel increases and hence the mixture ratio should made leaner to avoid rich evaporated fuel-air ratio.

2. **Acceleration and deceleration**

- Fuel evaporated in intake manifold moves faster than the liquid film formed on the induction system walls.
- When throttle is suddenly open, the liquid fuel lags behind and temporarily the engine cylinder receives a lean mixture whilst rich mixture is needed to produce instantaneous power for acceleration.
- To compensate for temporary leaning of mixture and to provide rich mixture needed for acceleration period, additional fuel must be supplied by suitable mechanism.
Drawback of Simple Carburetor

- At very low speeds, the mixture supplied by a simple carburetor is so lean that it will not ignite properly.
- The working of simple carburetor is affected by changes of atmospheric pressure.
- If the setting is done in winter season, it will give too rich mixture in the summer.
- It gives proper mixture at only one engine speed and load, therefore it is suitable only for engines running at constant speed.
- Quantity of fuel issuing out will change and not match with the velocity of air flowing through the venturi therefore proper mixture formation does not take place with increasing or decreasing speed.
- In simple carburetor, the mixture is lean, when the throttle is suddenly opened because of the inertia effect of fuel, which prevents proper fuel quantity from flowing immediately.

Compensating Devices

- The tendency of a simple carburetor is to progressively enrich the mixture as the throttle starts opening. The main metering system alone will not be sufficient to take care of the needs of the engine.
- Therefore, certain compensating devices are usually added to the carburetor along with the main metering system so as to supply a mixture with required air/fuel ratio.
- A number of compensating devices are in use. The important ones are:
  - Air-bleed jet
  - Compensating jet
  - Emulsion tube
  - Back suction control mechanism
  - Auxiliary air valve
  - Auxiliary air port
Air-bleed jet

- It contains air-bleed into main nozzle.
- An orifice restricts the flow of air through this bleed
- When the engine is not operating the main jet and the air bleed jet will be filled with fuel.
- When the engine starts, initially the fuel starts coming through the main as well as the air bleed jet.
- As the engine picks up, only air starts coming through the air bleed and mixes with fuel at making air-fuel emulsion.

Compensating Jet

- In this method, in addition to the main jet, a compensating jet is incorporated.
- The compensating jet is connected to the compensation well and it is vented to atmosphere
- The compensating well is supplied with fuel from the main float chamber through a restricting orifice.
- With the increase in airflow rate, there is decrease of fuel level in the compensating well, with the result that fuel supply through the compensating jet decreases. The compensating jet thus progressively makes the mixture leaner as the main jet progressively makes the mixture richer.
Emulsion Tube

- The mixture correction is attempted by air bleeding in modern carburetor.
- A submerged jet is located at the bottom of a well. The sides of the well have holes which communicate with the atmosphere.
- In the beginning the level of fuel in the float chamber and the well is same. When the throttle is opened the pressure at the venturi throat decreases and fuel is drawn into the air stream.
- This results in progressively uncovering the holes in the central tube leading to increasing air-fuel ratios.
- The air is drawn through these holes in the well, and the fuel is emulsified, the pressure differential across the column of fuel is not as high as that in simple carburetor.

Types of carburetors

There are 3 general types of carburetors, depending on the direction of flow of air.

a) **Updraught**

- Air enters at the bottom and leaves at the top hence the direction of the flow is upward.
- The disadvantage is that it must lift the sprayed fuel droplet by air friction.
Types of carburetors

b) Downdraught

- It is used to overcome the drawback of downdraught carburetor.
- It is placed at a level higher than the inlet manifold and air and mixture generally follow a downward course. Here fuel does not have to lift by air friction but move into the cylinder by gravity even if the air velocity is low.

![Downdraught Diagram]

Types of carburetors

c) Cross-draught

- It consists of a horizontal mixing tube with a float chamber on one side of it. It reduces the resistance to flow by eliminating the right angle turn in the inlet passage.

![Cross-draught Diagram]
Thanks