Fuel metering system in si engines

Carburetor: is a device which is used in automobiles, with spark ignition engines, for the purpose of fuel metering, i. e. to mix the appropriate amount of fuel with the incoming air which is to be supplied to the engine cylinders.

The basic principle upon which the carburetor works is flow of air through the venturi. The fuel enters the carburetor through the air filter, which filters the air to remove any dust particles in the air; passing through the choke valve it enters the venturi (a converging-diverging nozzle), where due to decrease in cross-sectional area, the velocity of the air increases, decreasing the pressure in that area. A decrease in the pressure results in fuel flowing out of the float chamber and mixing with the air, hence forming an air-fuel mixture.

Figure . Cross-sectional view of a basic carburetor

Basic Requirements:

In a spark ignition engine the torque and power output of the engine is controlled by controlling the amount of air-fuel mixture that enters the engine cylinder; and this is done by incorporating a butterfly valve (throttle valve) in the carburetor.

In order to achieve complete combustion inside the engine cylinder and avoid the wastage of fuel into the exhaust, a stoichiometric mixture is required; which is a mixture that contains precise proportions of fuel and air required for the complete combustion of both the fuel and the air, which is equally important. In gasoline engines, this ratio is around 15: 1. Even if this ratio is achieved, practically the mixture is still not combusted completely owing to the extremely short time available to the air-fuel mixture for combustion. The air-fuel mixture is unable to form a completely homogenous mixture resulting in exhaust gases containing traces of oxygen, carbon monoxide and some unburned and partially burnt fuel. The range of air-fuel ratio for ignitable mixture varies from 18: 1 to around 7: 1.

The basic purpose of using a carburetor is to:

Measure the airflow of the engine

Deliver the correct amount of fuel to keep the air-fuel mixture in the proper range

Mix the air and fuel finely and evenly

The proper air-fuel mixture is required to be delivered to the engine cylinder at the various commonly faced conditions during the vehicle operation, namely:

Cold start

Hot start

Idling or slow-running

Acceleration

High speed/high power at full throttle

Cruising at part throttle

The deficiencies of the elementary/early carburetor:

At low loads the mixture becomes leaner; the engine requires the mixture to be enriched at low loads.

At intermediate loads, the mixture equivalence ratio increases slightly as the air flow increases. The engine requires an almost constant equivalence ratio.

As the air flow approaches the maximum wide-open throttle value, the equivalence ratio remains essentially constant. However, the mixture equivalence ratio should increase to 1. 1 or greater to provide maximum engine power.

The elementary carburetor cannot compensate for transient phenomena in the intake manifold. Nor can it enrich the mixture during engine starting and warm-up.

The elementary carburetor cannot adjust to changes in ambient air density (due primarily to changes in altitude).

Modern Carburetor Design:

The changes required in the elementary carburetor for better and more efficient performance are:

The main metering system must be compensated to provide essentially constant lean or stoichiometric mixtures over the 20 to 80 percent air flow range.

An idle system must be added to meter the fuel flow at idle and light loads.

An enrichment system must be added so the engine can provide its maximum power as wide-open throttle is approached.

An accelerator pump which injects additional fuel when the throttle is opened rapidly is required to maintain constant the equivalence ratio delivered to the engine cylinder.

A choke must be added to enrich the mixture during engine starting and warm-up to ensure a combustible mixture within each cylinder at the time of ignition.

Altitude compensation is required to adjust the fuel flow to changes in air density.

It is also necessary to increase the magnitude of the pressure drop available for controlling the fuel flow.

Figure . Modern Carburetor design

Basic Working and different parts of the Carburetor:

Figure . Simple Carburetor with additional basic features

1)

Float

2)

Float needle

3)

Float chamber

4)

Main jet

5)

Air tunnel(venture)

6)

Throttle plate (a. no-load operation) b. partial load; c. full load)

7)

Air correction nozzle

8)

Mixing tube

9)

Mixing tube holes

10)

Enrichment pipe

11)

Jet (calibrated drilling)

12)

No-load operation fuel nozzle

13)

Idle run air duct

14)

Idle mixture adjustment screw

15)

Bypass drilling

16)

Accelerator pump

17)

Choke (for cold start)

18)

Ventilation

A carburetor basically consists of an open pipe, a throat/barrel through which the air passes into the inlet manifold of the engine. The pipe is in the form of a venturi; it narrows in section and then widens again, causing the airflow to increase in speed in the narrowest part. Below the venturi is a butterfly valve called the throttle valve (a rotating disc that can be turned end-on to the airflow), so as to hardly restrict the flow at all, or can be rotated so that it almost completely blocks the flow of air.

This valve controls the flow of air through the carburetor throat and thus the quantity of air/fuel mixture the system will deliver, thereby regulating engine power and speed. The throttle is connected, usually through a cable or a mechanical linkage of rods and joints or rarely by pneumatic link to the accelerator pedal on a car or the equivalent control on other vehicles or equipment.

Fuel is introduced into the air stream through small holes at the narrowest part of the venturi and at other places where pressure will be lowered when not running on full throttle. Fuel flow is adjusted by means of precisely-calibrated orifices, referred to as jets.

Idle circuit: As the throttle plate is opened slightly from the fully closed position, the additional fuel delivery passages are uncovered behind the throttle plate. The low pressure area is created due to the throttle plate blocking the air flow; this allows more fuel to flow as well as compensating for the reduced vacuum that occurs when the throttle is opened. This smoothens the fuel flow through the jets when moving from closed throttle position to the open throttle circuit.

This circuit plays its role when the engine is running on no load condition or is known as “ idling”. The air enters from the idle run air duct, certain amount of fuel is mixed with this air depending on the no-load operation fuel nozzle and then goes into the intake manifold through the idle mixture screw path. This idle mixture screw is adjusted to regulate the amount of air-fuel mixture when idling.

Main open-throttle circuit: When the throttle is opened, the vacuum inside the manifold decreases due to decreased restriction in the airflow. This reduces the flow through the idle and off-idle circuits. The airflow through the throat increases, and in accordance with the Bernoulli's principle the pressure drops in the throat and the fuel flow through the jet, which is placed in the centre of the venturi, increases.

Similarly, when the throttle is closed, the airflow through the venturi drops till the point when the lowered pressure is insufficient to maintain the fuel flow, and the idle circuit takes over. At times booster venturis are used to enhance the fuel flow out of the jet and into the air stream.

Accelerator Pump: The inertia of the liquid gasoline is more than that of the air, which shows that when the throttle is opened suddenly during sudden acceleration, the amount of air that will flow would be far greater than the amount of fuel flow resulting in a temporary lean mixture, causing the engine to stumble under acceleration. This is not a desirable effect. In order to eliminate this unwanted effect, a small mechanical pump usually of diaphragm type is employed. It propels a small amount of gasoline through a jet, from where it is injected into the carburetor throat. This extra shot of fuel counteracts the transient lean condition during sudden acceleration.

The accelerator pump is also used to prime the engine with fuel prior to a cold start. Excessive priming, like an improperly-adjusted choke, can cause flooding. This is when too much fuel and not enough air are present to support combustion. For this reason, some carburetors are equipped with an unloader mechanism: The accelerator is held at wide open throttle while the engine is cranked, the unloader holds the choke open and admits extra air, and eventually the excess fuel is cleared out and the engine starts.

Choke: when the engine is cold, the fuel does not vaporize properly, instead it condenses on the walls of the intake manifold, and hence very little fuel is delivered to the cylinders. This makes it difficult for the engine to start. This calls for the need of a richer mixture to start and run the engine until it warms up, as the richer mixture is easier to ignite.

Figure . Cross-sectional view of a choke

To provide the extra fuel, a choke is typically used. It is a device that restricts the flow of air at the entrance to the carburetor, before the venturi. With this restriction in place, extra vacuum is developed in the carburetor barrel, which pulls extra fuel through the main metering system to supplement the fuel being pulled from the idle circuit. This provides the rich mixture required to sustain operation at low engine temperatures.

Even in this era of advanced technology, cars like Suzuki Mehran still employ a choke which is connected to a pull-knob on the dashboard operated by the driver. In some carbureted cars it is automatically controlled by a thermostat employing a bimetallic spring, which is exposed to engine heat, or to an electric heating element. This heat may be transferred to the choke thermostat via simple convection, via engine coolant, or via air heated by the exhaust. More recent designs use the engine heat only indirectly: A sensor detects engine heat and varies electrical current to a small heating element, which acts upon the bimetallic spring to control its tension, thereby controlling the choke.

A choke unloader is a linkage arrangement that forces the choke open against its spring when the vehicle's accelerator is moved to the end of its travel. This provision allows a flooded engine to be cleared out so that it will start.

Some carburetors do not have a choke but instead use a mixture enrichment circuit, or enrichener. Typically used on small engines, notably motorcycles, enricheners work by opening a secondary fuel circuit below the throttle valves. This circuit works exactly like the idle circuit, and when engaged it simply supplies extra fuel when the throttle is closed.

Float chamber: To ensure a ready mixture, the carburetor has a float chamber or bowl that contains a quantity of fuel at near-atmospheric pressure, ready for use. This reservoir is constantly replenished with fuel supplied by a fuel pump.

Float: The correct fuel level in the bowl is maintained by means of a float controlling an inlet valve. The fuel arriving from the tank is held inside a constant level float chamber. The liquid pressure head on the various jets is relatively constant.

The float chamber level is kept constant by means of a fuel inlet valve, actuated by a float that follows free surface of the liquid in the float chamber. As fuel is used up, the float drops, opening the inlet valve and admitting fuel. As the fuel level rises, the float rises and closes the inlet valve. By having a high float level, a greater fuel quantity is delivered compared to the case with a low float level, under all operating conditions and for all of the carburetor's circuits.

Vent Tubes: Usually, special vent tubes allow air to escape from the chamber as it fills or enter as it empties, maintaining atmospheric pressure within the float chamber; these usually extend into the carburetor throat. Placement of these vent tubes can be somewhat critical to prevent fuel from sloshing out of them into the carburetor, and sometimes they are modified with longer tubing.

Notch Pin: With this type of carburetor, the maximum depression zone is beneath the throttle valve (slide) which is raised and lowered by the throttle cable, controlling the speed of the engine.

As shown in the drawing, the bottom of the slide features a tapered needle which fits into the fuel pick-up tube (needle jet) to meter the fuel delivery of the tube from about 1/4 throttle to 3/4 throttle. From 3/4 throttle to full throttle, the needle will not affect the fuel flow. At this point, fuel flow is metered by the main jet (position at the bottom of the tube).

The setting of the notch determines the amount of fuel being allowed to mix with the incoming air; notch 1 providing a lean mixture and richer mixture as we proceed to notch 4.

Figure 11. Notch Pin

Types of Carburetors:

Carburetors can be classified into three types:

Float Feed

Suction Feed/Diaphragm

Constant Vacuum/Constant Depression/Zenith-Stromberg

The difference between these is the way the fuel is supplied to the Air Stream.

Float Feed:

Float feed carburetors are so named because they maintain a fuel staging area at approximately ambient pressure with a float valve. Fuel level is maintained to tight tolerances because fuel metering is a function of float level. Higher levels make it richer.

Figure 12. Operation of needle valve

As the fuel is drawn for the bowl area the float drops, opening the float valve. Then the fuel pump pressure causes the bowl to refill, floating the valve closed. Under normal operations the float valve remains slightly open to very open, keeping the level constant.

Floats can be concentric or eccentric. Concentric are levers, first or second class, whereas eccentrics are a slide float. Floats can be adjusted by shims under the valve or by adjusting a valve contact tab. Floats need to be carefully inspected for leaks and possible deterioration.

The main source of fuel metering force comes from the pressure differential between the low pressure area within the venture and the ambient pressure in the float chamber, or bowl. This is called air metering force.

Figure 13. Air-metring force being applied

Idle circuits will exist that feed fuel through separate ports. These are located just downstream of the throttle plate; there may also be transition ports to assist throttle transition from idle to midrange. Idle and transition ports will only be active when throttle plate is closed or transitioning (they function only when the throttle plate is causing high velocity air or flow close to the port and once the throttle plate opens enough, the port stops delivering fuel flow); these ports usually form a completely separate fuel circuit from the main fuel metering. They may also have air bleed systems.

Figure 14. Demonstration of relation between Idle circuit and main throat operation

Most of these carburetors are up draft or side draft, and the systems are identical with the position of the fuel discharge venturis and idle circuits upstream of the throttle valve, regardless of the airflow direction.

Figure 15. An up-draft carburetor

Disadvantages:

The three major disadvantages of float carburetors are:

Various flight attitudes may cause the float system to malfunction.

Carburetor icing is most prevalent with this type.

Fuel metering and throttle transition is less accurate.

Suction Feed:

Suction Feed Carburetor is very similar to the float type. The one exception is there is no float to meter and control the level of fuel in the fuel chamber. The difference in pressure between the tank and the carburetor throat lifts the fuel up the fuel pipe past the main needle valve and through the discharge holes.

Figure 16. Suction Feed Carburetor

Figure 17. Cold Start Figure 18. Idling

Constant Vacuum:

The constant vacuum carburetor has a rubber diaphragm exposed to the cylinder intake stroke vacuum on one side and to atmospheric pressure on the other. The diaphragm moves against the inlet needle (cylindrical slide valve) allowing it to move from its seat. A spring returns the needle (cylindrical slide valve) to its seat when the vacuum stops.

Figure . A typical Constant Vacuum type carburetor

A few advantages of Carburetors:

Carburetors are much easier to adjust/less technical skills required

Cheaper to repair & rebuild

Less special equipment required.

Problems with Carburetors:

Have mechanical parts due to wear and tear needs periodic adjustments and maintenance.

Flexibility limitations.

Intake manifold length problems in the case of multi cylinder engines

Carburetors aren't very efficient as they can't make changes on the fly like fuel injection can.

Conclusions:

Keeping in mind the advantages and disadvantages of carburetor, regardless of the constant n continuous effort to improve the basic design into the most efficient one, the carburetors have finally been replaced by the latest technology referred to as fuel injectors.

These fuel injectors are of various types, GDI being a personal favourite and the best technology available in the market. The fuel injectors efficiently meter the appropriate amount of fuel hence reducing the exhaust emissions, fuel wastage, the harmful pollutants and giving the best fuel economy possible.