Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 6; April-June, 2015 pp. 496-501

http://www.krishisanskriti.org/jbaer.html

Fuel Injection System an Advancement in Fuel Supply Systems

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Abstract—*Fuel injection is a system for admitting fuel into an internal combustion engine. A modern injector is an in charge of providing a measured amount of fuel into the combustion chamber. It has become the primary fuel delivery system used in automotive engines, having replaced carburetors. A variety of injection systems have existed since the earliest usage of the internal combustion engine. There are various types of processes involved in the injection such as throttle body injection, direct injection and multipoint fuel injection. They are also divided based on type of injectors and also the areas where the injection is carried on. The introduction of injection has proved fruitful in bringing out revolutionary changes in cars such as hybrid cars and multi fuel usage cars.*

Keywords: *Injection, spray pattern, atomization, ECU, Hybrid cars, multi-fuels, efficiency, engine size.*

1. INTRODUCTION

Fuel Injection system is the most vital component in the working of a CI engine as well as an SI engine these days. The engine performance parameters such as economy, power output etc. depend on the effectiveness of the fuel-injection system. The injection system has to perform duties such as initiating and controlling the amount of the fuel during the combustion process.Generally the basic function of any fuel supply system is to prepare a combustible charge that can meets the requirements of load conditions and riding conditions i.e. whether in speeding and cruising conditions of a vehicle in order to maximise the performance of engine. We are aware of the difference in processes that undergo in carburetion and fuel injection, in carburetion a fuel air mixture is prepared where as in injection air is compressed and then fuel is then injected

(Atomised & pressurised) into chamber through injectors for combustion.

The need for fuel injection systems in the present economic and environmental conditions are:

- Accurate metering of fuel for fuel efficiency
- Controlled rate of injection for controlled thermodynamic conditions
- Accurate timing for maximum power
- Proper atomisation for a better air fuel mixture
- Equal quantities of fuel into a multi cylinder engine
- To eliminate dribbling of fuel into the cylinder

2. CLASSIFICATION OF FUEL INJECTION SYSTEMS

2.1. Based on the type of power source

- Mechanically controlled Fuel Injection system
- Electronically controlled Fuel Injection System

Mechanically controlled system

In this system the fuel is injected through injectors which are controlled mechanically with the help of plunger feed pump. The shafts of plunger feed pumps are attached to the crankshaft of the engine which is the source of power for building the required pressure into the fuel injectors.

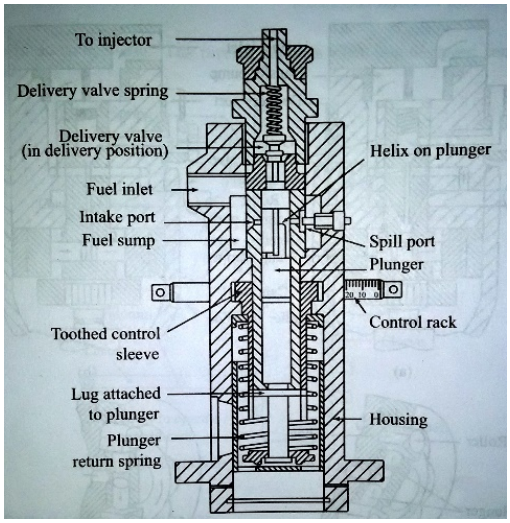

Fig. 1: Mechanical Fuel Injection pump

The fuel injectors are also mechanically powered devices which have a spring strained plunger releasing on exceeding the required pressure. Piston of a feed pump rocks powering

from the crankshaft. The to and fro motion the piston in the fuel feed pump builds the required pressure into the fuel lines through which the fuel is sent into the fuel injector. Here the fuel injector has a plunger which is kept in action with the help of a spring. The plunger is lifted up when the pressure inside the injector exceeds the spring constant and is injected into the combustion chamber.

Electrically controlled system

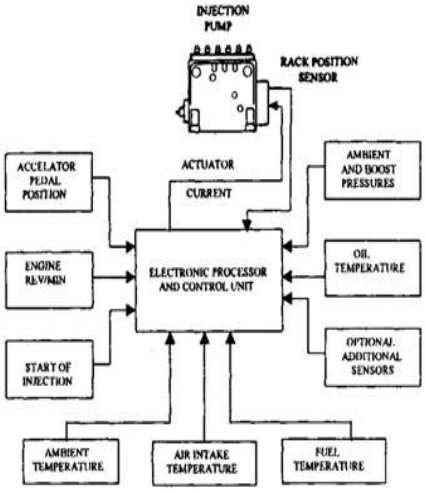

Fig. 2: Engine control unit Block Diagram

In this system the fuel pump and fuel injector are all controlled electrically and power source is the electricity which is mostly the power from battery of the automobile. The inputs parameters for the injection pressure, quantity etc. are controlled by ECU (Engine Control Unit) which is the brain of automobiles these days. The accurate parameters are decided using the CPU of ECU and are sent as electrical impulses to the fuel pump and also to the injector. The timing of the injection, amount of fuel and pressure of spray.The constructive parts of an electrical fuel injection system include sensors which are the sensory organs of the brain of the automobile i.e., ECU. Sensors detect the minute changes in the engine conditions and accordingly send signals to the ECU for the desired reactive operations to be carried upon. The sensors usually used are:

Oxygen Sensor: Senses the amount of oxygen in the exhaust and calculates the air fuel ratio.

Engine Temperature Sensor: Senses the temperature of the engine coolant there by adjusts the mixture accordingly rich or lean mixture for cold starting conditions.

Air Flow Sensor: Monitors the volume of air flowing into the intake manifold.

Air Inlet Temperature Sensor:Checks the temperature of air in the intake manifold for regulating the mixture of fuel.

Throttle Position Sensor: Senses the movement of throttle to analyse the actual speed and acceleration

Manifold Pressure Sensor: Monitors the vacuum in the intake manifold, so that the mixture strength can be adjusted accordingly to the load.

Camshaft position Sensor: Senses the rotation of engine camshaft and crankshaft for speed and accordingly timing of injection.

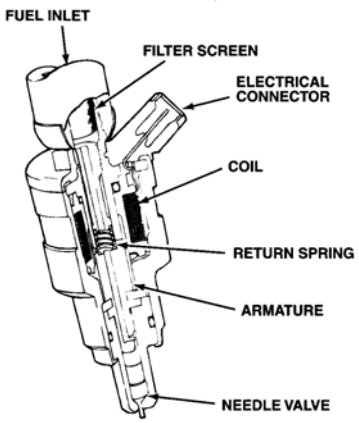

Fig. 3: Electrical Fuel Injector

Knock sensor: A microphone which senses the pre-ignition noise so that the timing of ignition can be adjusted.

2.2. Based on the Principle of Injection

- Air injection System
- Solid injection system

Air Injection System

In this system fuel is forced into the cylinder by means of compressed air. The fuel is mixed with air efficiently as it is sent through compressed air. This method is least followed because in order to pump the compressed air there is a need of compressor which would add an extra weight to the engine reducing the brake power output further.

Solid Injection system

In this system the fuel is injected directly into the chamber without the aid of compressed air. Hence it is also called as airless mechanical injection or solid injection system. The pressurised fuel from the pump is sent directly to the injector in the case of a single cylinder system and in sent in different ways to the multi cylinder system with mechanisms likedistributor system, common rail system etc.

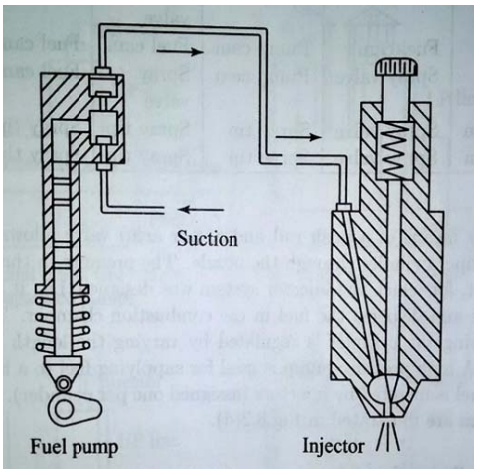

Fig. 4: Solid Fuel Injection

2.3. Based on the type of injection

- Throttle Body injection
- Multipoint injection
- Direct injection

Throttle Body Injection

In this type of injection usually a single point injector placed before the throttle plate; looks much like a carburetor. The injector injects the fuel into the air intake housing which results in proper mixing of the fuel with air. One injector feeds all the cylinders.In some applications, two injectors may be used side by side.Usually TBI systems run low pressure (15 psi) fuel systems. This type of injection is mostly electronically controlled. The control unit senses the requirements of the fuel such as volume, pressure and the duration for which it has to be sprayed and the respective signals to the hardware are sent in the form of pulses of varied electric voltagesfor accurate spraying of fuel. The problem with the TBI is that different amount of fuels are supplied to different cylinders. Hence this type of injection has been ruled out in case of multi cylinder engine.

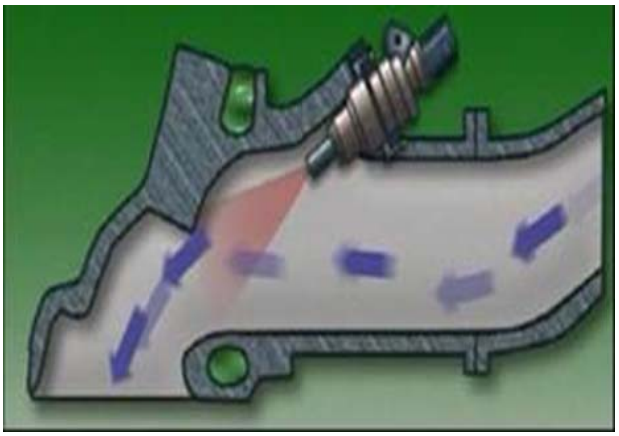

Fig. 5: Throttle Body Injection

Multipoint Injection

This type of injection is generally used in a multi cylinder engine. Each cylinder is equipped with a separate injector. At the time of starting, the cold start injector injects fuel into the intake chamber thus enriching the fuel-air mixture. Each injector assigned to each cylinder receives signal form the ECU separately and executes the signal pulse obtained in order to spray the correct amount of fuel at the correct time for proper timing of the combustion. Using MPFI provides us the ease of locating a fuel injector where ever necessary to meet the purpose in the modernized automobiles. Even though MPFI was able to spray fuel equally into the cylinders. But it was spraying the fuel at the intake manifold, so the fuel pressures are comparatively low. Hence there was a need for improvised spray pressures of fuels.

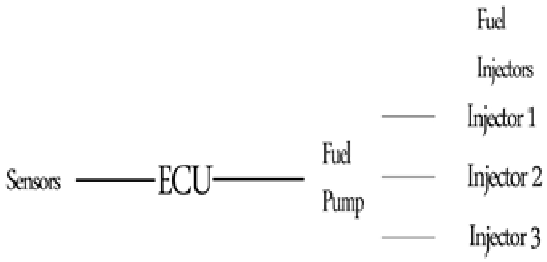

Fig. 6: MPFI layout

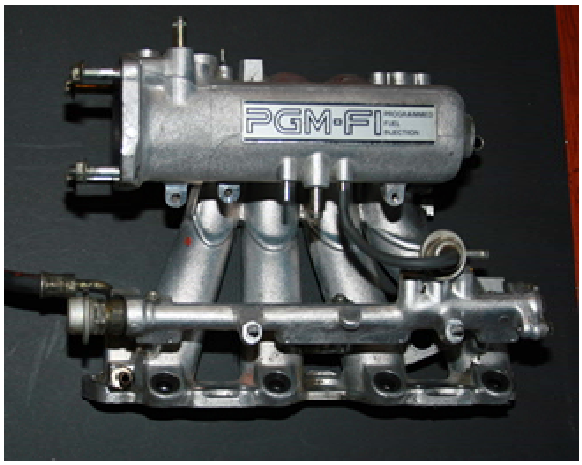

Fig. 7: MPFI

Direct Injection System

In a direct injection system, the injectors directly spray the fuel into the combustion chamber which will solve the problem of drop in pressures. The DI (Direct Injection System) is the most used in the present day passenger cars. Usage of DI nearly increased 15 % of efficiency in fuel consumption and 6% increase in the effective brake power due to the simple and light construction.

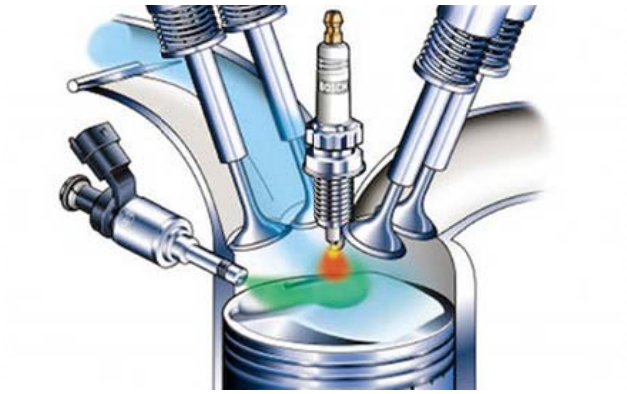

Fig. 8: Direct Injection (DI)

3. FUEL INJECTORS

As mentioned above we have 2 broadly classified injectors based on power source

3.1 Mechanical

Fuel enters form the fuel inlet and fills the fuel passage, upon filling the fuel which is further coming builds the pressure inside the fuel passage. The increased pressure exerts force on the nozzle which is connected to a spring loaded spindle. The excess pressure force lifts the nozzle and the fuel is sprayed at a high pressure. Spring helps in immediate closing of the opened injector.

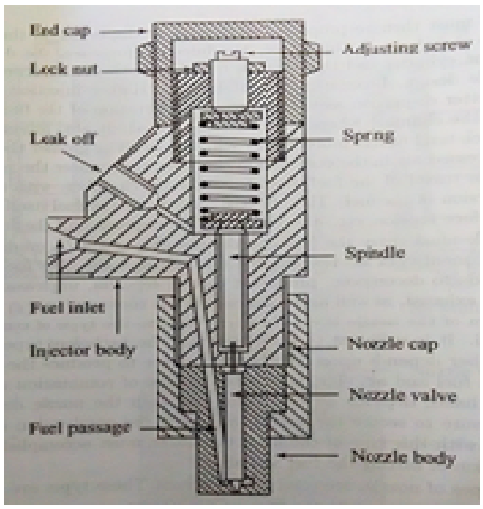

Fig. 9: Mechanical Fuel Injector

3.2 Electrical

In an electrical type of injector, the injector is usually connected to a 12volt battery supply. Processed signals from Sensors to ECU are carried forward to the injector. The injector then executes the signal pulse injecting the correct amount of fuel at correct pressure and spray.

4. NOZZLES

The nozzle of a fuel injector is part through which the fuel is sprayed. A nozzle should fulfill the following functions.

- Atomization
- Distribution of fuel
- Prevention from spraying onto the walls
- Mixing

Depending upon the nozzle, the injectors are classified into 4 types:

- Pintle nozzle
- Single hole nozzle
- Multi hole nozzle
- Pintaux nozzle

Pintle Nozzle

The stem of nozzle valve is extended from a pin or pintle which protrudes through the mouth of nozzle. The size and shape of pintle can be varied according to requirement. It provides a spray operating at low injection pressures of 8-10 MPa the spray cone angle is 60 degrees

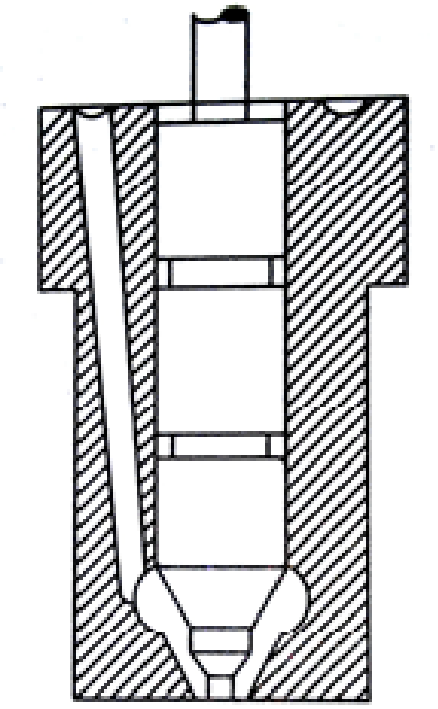

Fig. 10: Pintle nozzle

Single hole nozzle

At the Centre of nozzle body there is a single hole which is closed by the nozzle valve. Hole size is 0.2mm. Injection pressure is of order 8-10 MPa and spray cone angle is 15 degrees.

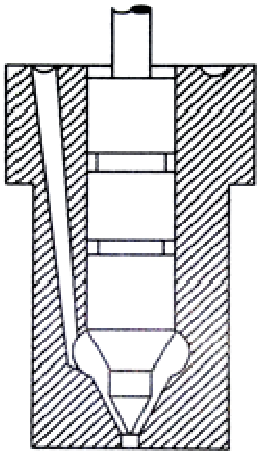

Fig. 11: Single hole nozzle

Multi Hole Nozzle

It consists of a number of holes bored in the tip of nozzle. The number of holes varies from 4 to 18 and size is from 35 to 200 µm. The hole angle may be from 20 degrees upwards. These nozzles operate at high injection pressures of the order of 18 MPa

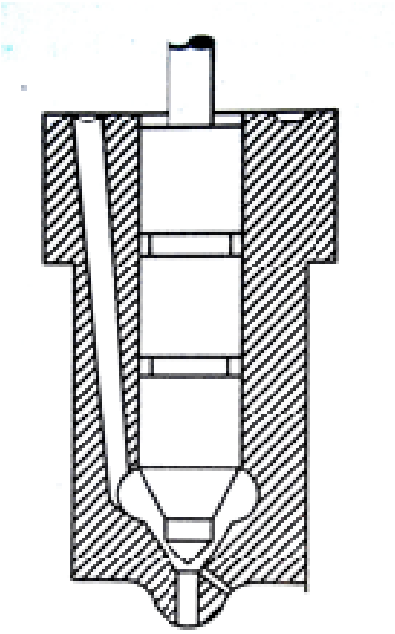

Fig. 12: Multi hole nozzle

Pintaux Nozzle

It is a type of pintle nozzle which has an auxiliary hole drilled in the nozzle body it injects a small amount of fuel through this additional hole which is called pilot injection in the upstream direction slightly before main injection. The needle valve does not lift fully at low speeds and most of the fuel is injected through the auxiliary hole. The main advantage of this nozzle is better cold starting performance.

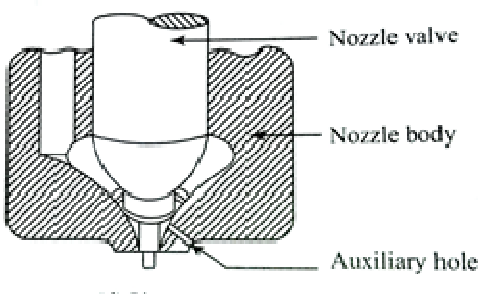

Fig. 13: Pintaux nozzle

5. APPLICATIONS

The applications of fuel injection include automobiles like passenger cars, heavy trucks, car which run on multi fuels and also in the latest trending invention of hybrid cars. The injection provides the freedom of spraying the precise and accurate amount of fuel at accurate timing and when needed. For example in case of a hybrid car which is required to stop and start automatically, the electrical system in the injection provides and ease of functioning. The electrical signals trigger the necessary actions of injection and determine the speed and also cut off the supply. It also receives the signals when about starting directly.

The results yielded on conducting experiment on an engine in our laboratory with injection and carburetion are as follows

6. ADVANTAGES

- Improvements in the volumetric efficiency
- Manifold wetting is eliminated
- Proper atomization of fuel
- Formation of ice on throttle plate is eliminated
- Fuels of varied volatilities can be used
- Proper air fuel ratios
- Decrease in size of engine due to compact construction

Table 1: Fuel consumption with carburetion

Load on engine (kg)	Speed of engine (rpm)	Fuel consumption (kg/hr)
No loading	1500	3.05
10	1500	3.32
20	1500	3.57
30	1500	4.12
40	1500	4.18

Table 2: Fuel consumption with injection

Load on engine (kg)	Speed of engine (rpm)	Fuel consumption (kg/hr)
No loading	1500	2.86
10	1500	3.11

20	1500	3.42
30	1500	4.02
40	1500	4.46

7. DISADVANTAGES

- High maintenance cost
- Difficulty in servicing
- Possibility of malfunctioning

But these disadvantages can be eliminated with the help of techniques like mass production vigorous training and increase in quality of production techniques.

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