Direct Petrol Injection

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MITSUBISHI GASOLINE DIRECT INJECTION ENGINE

The GDI tm (**Gasoline Direct Injection**)engine was developed by Mitsubishi Motors Corporation to achieve two main objectives.

Fuel economy at partial loads superior to that of a diesel engine which provides for energy saving and the reduction of CO2 emission, one of the most harmful green house effect gases, and higher power output than can be achieved from conventional **Multi Point Injection** (**M.P.I**) engines.

This has been realised through computer aided engineering which allowed innovative engine design particularly for the combustion chamber, piston top, manifolds and the strategic positioning of the in cylinder injector.

High power engine management allows sophisticated control of the exact point or points in the firing cycle that fuel could be injected. This means fuel can be injected during the induction stroke providing a homogeneous charge (a uniformly mixed charge similar to that created in a conventional M.P.I engine) or during the compression stroke at between 10 to 60 degrees BTDC crank angle. Providing a stratified (non uniformed) prepared Mixture just prior to the ignition point.

For reference the GDI is essentially the same as a conventional M.P.I engine apart from the combustion chamber, intake manifold and the fuel delivery system.

HISTORY:-

Directly injecting fuel into the combustion chamber of a petrol engine is not new, but developing it to the point were it could be used successfully in a normal production vehicle has eluded many previous attempts, so lets briefly look at the history of direct injection technology.

Before highly sophisticated carburetors were invented, aircraft in the forties used D.I technology based on diesel fuel injection systems, however, this soon disappeared with the progress of carburetor technology.

In 1954 the Benz 300SL used D.I to try to overcome the inherent deficiency of carburetors of that time. However, this was short lived due to Benz adopting the port injection system.

Up until this time the early fuel injection strategy was used that is the fuel was injected during the intake stroke making it a homogeneous mixture, consequently the objective was not on fuel economy or emissions but rather to boost performance.

Later attempts in the 60's and 70's concentrated on fuel efficiency and so fuel was injected early to provide a stratified charge. To try and obtain complete combustion while using extremely lean mixtures, the comparatively rich pockets of stratified charge were directed toward the spark plug in a effort to ensure stable combustion.

Although stable combustion was realised the following problems prevented the D.I from going into production.

1. Hydrocarbon emission:- was unacceptably high because it was difficult to get complete combustion

2.Air swirling used to promote air fuel mixing was dependent on sufficient engine speed while the fuel spray was not. This limited the engines speed range where sufficient air mixing could take place.

3. Spark plug fouling occurred because the rich mixture directed towards the spark plug caused sooting.

4. Poor performance resulted because late to early injection was not possible so the engine was operated on a late stratified charge even in the high load range where it was difficult to obtain maximum power output operating under lean burn conditions.

5. The lubricating oil became diluted because it was difficult to prevent raw fuel droplets impinging on the cylinder liner and piston surface. This raw fuel ended up being unburned and consequently became an HC emission as well as diluting the lubricating oil.

6. Excess soot emission and carbon build up also became an insurmountable problem.

By now you may appreciate the difficulties of directly Injecting fuel into petrol engines and what Mitsubishi had to overcome to achieve a D.I. engine especially in today's stringent emission environment.

So now lets have a look at the GDI engine in some detail. First of all the combustion chamber:- this is a pent roof design with an upright straight intake port. This causes a tumble down effect rather than the swirl previously used, the specially shaped piston top redirects the air fuel mixture towards the centre mounted spark plug thereby providing an ideal air fuel ratio at the spark plug to ensure good combustion characteristics during super lean air fuel mixtures and good flame propagation to the leaner areas of the cylinder.

As mentioned previously fuel can be injected on the induction stroke (early injection) or the compression stroke (late injection) or both induction and compression which is called two stage mixing. The engine is automatically adjusted by the engine management system to run in basically four modes as follows:-

1. **SUPER LEAN :-** during this mode the engine utilizes the late injection strategy (stratified) and operates at 40.0:1 A.F.R .

2.**LEAN BURN :-** this mode also utilises late injection or two stage mixing and operates at about 22.0:1 A.F.R. Both the above modes provide superior fuel economy and consequently lower CO2 emission levels. Lean modes as appropriate will be selected at light loads up to about a 120km/hr .

3.**STIOCHOMETRIC** :- mode is selected to provide high power output and uses early injection stratigy (homogeneous) and therefore operates similar to conventional M.P.I engines but with increased power thanks to the 12.5:1 compression ratio which can be used in the GDI due to the cooling effected provided by the fuel vaporising in the cylinder absorbing heat in the same way that the air conditioning refrigerant does (charge cooling effect).

The other modes are the rich mode for starting and accelerating and the fuel cut mode to turn fuel off during deceleration to protect the emission equipment. These last two modes are a standard part of port injection and are not peculiar to the GDI. In the lean modes the engine is operated in an unthrottled condition as in the case of a diesel engine. This is achieve with the use of two bypass valves or in some models by using Mitsubishi's E.T.V (**E**lectronic **T**hrottle **V**alve) system in either case the engine computer causes air to be supplied to the engine directly and so engine torque is determined by the amount of fuel supplied to the engine.

For reference the **E.T.V system** uses a high torque electric motor so the throttle valve is driven by electrical signals from the computer, there is no accelerator cable or hard equipment to operate the throttle valve, from the accelerator pedal.

The fuel injection system is almost identical to that of a normal M.P.I petrol system except for the following;

A normal in-tank feed pump is used to supply fuel to the high pressure pump which is driven off the back of the cylinder head by the exhaust camshaft. The high pressure pump is a single plunger type and takes the fuel from the lift pump at about 340 k.p.a and increases it to 5 m.p.a (710 p.s.i) to supply to the injectors. During starting the high pressure pump cannot deliver sufficient pressure so fuel is supplied directly by the low pressure feed pump. Special attention was given in the design of the high pressure pump because petrol does not provide the lubricating properties that diesel fuel does, therefore internal tolerance and design is different to that of a diesel engine pump. For this reason the high pressure pump is a non - serviceable item.

The high pressure swirl injectors which are the normal pintle electromagnetic type efficiently disperse the injected fuel so that it is highly atomised and away from the cooler cylinder liner. They are driven on by applying 100 volts D.C at 20 amps and then held on by normal system voltage the high voltage is necessary in order to get the injector to respond quickly (about four times faster than conventional types). They also have a high decree of self cleaning ability due to the action of the high pressure fuel being continuously sprayed through them.

IGNITION SYSTEM

The ignition system used on G.D.I is the high energy type which is the standard type used on all M.P.I systems nowadays.
This system has an open circuit potential of 50,000 volts so there's plenty of energy to take care of the G.D.I 's requirements.

However, the G.D.I does use a direct fire system to maintain durability as regular service intervals are 15,000 / 1 year. The direct fire system utilises an ignition coil on top of each spark plug whereas the M.P.I uses a waste spark system which has one ignition coil for each pair of spark plugs. The ignition curve characteristics are of course quite different also. In all other respects the two systems are the similar.

Nox emission

One of the biggest draw backs of lean burn engines is the unacceptable amount of nox emission. To overcome this the G.D.I engine runs with a very high tolerance of **E.G.R** (exhaust recirculation)up to 30% when running in super lean mode.
Also a special 3 way lean reduction catalyst is also used which is effective at A.F.R beyond stoichiometric range.

So there we have it, an engine that is still not fully developed but in its present form capable of up to 40% improvement in fuel usage with an extra 10% increase in power output over comparable **M.P.I** petrol engines. In terms of a passenger car power plant a viable replacement for the small diesel engine.

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