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Performance Analysis of Gasoline Direct Injection inTwo Stroke Spark-ignition Engines

Dr.R. Kiruba Shankar [1], E.B. Priyanka[2], B. Saravanan[3]

Assistant Professor (SRG), Department of Mechatronics, Kongu Engineering College, Erode, India[1]

PG Student, Department of Mechatronics, Kongu Engineering College, Erode, India[2]

UG Student, Department of Mechatronics, Kongu Engineering College, Erode, India[3]

ABSTRACT:The advent of increasing fuel consumption and stringent emission standards have driven the need to introduce new technologies and modifications that reduces fuel consumption while meeting increasingly stringent exhaust emission standards. A key objective is the potential combination of gasoline-engine specific power with diesel engine efficiency in a cost-competitive, production-feasible power train. One promising engine development route for achieving these goals is the potential application of lean burn direct injection for gasoline engines. In carburettors, the fuel is sucked due to the pressure difference caused by the incoming air. On the other hand the fuel is injected into the air for more powerful, fuel-efficient and environmentally friendly gasoline engines, developing highly efficient, Ultra Low Emission Vehicles (ULEV's) by developing Gasoline Direct Injection (GDI) systems by controlling the mixture formation of a GDI engine under a wide range of engine operating conditions is essential to reduce smoke and particulate generation and optimize fuel economy. In this paper, a two-stroke engine is modified to work with direct gasoline injection system.

KEYWORDS: Two-stroke petrol engine, Direct Injection, Electronic Control Unit, Emission control, Optimization.

I.INTRODUCTION

The salient features of gasoline two-stroke engines over their four stroke counterparts are high power to weight ratio, less components, simpler construction and low cost. Two stroke engines have fewer components than four stroke engines typically because the two-stroke engines use no valves, cams, camshaft, valve trains, conventional heavy springs, belts etc. The piston of the Two-stroke reciprocating engine takes over valve functions in order to obtain a power stroke for each revolution of the crankshaft. The air and mixture flow in and out of the combustion chamber through the ports of the cylinder walls. The piston movement will cover and uncover the ports at correct time for maximum fluid exchange inside the combustion chamber. During the scavenging process, the intake and exhaust ports (at certain duration) are both opened at the same time and some of the fresh air/fuel charge is lost out of the Exhaust port. This loss of fresh fuel is called short-circuiting.

Mixing consists on the fact that there is a small amount of residual gases which remain trapped without being expelled, being mixed with some of the new air charge. Also in traditional two-stroke engines the fuel air mixture disperses widely within the combustion chamber leaving a substantial amount of fuel unburned. A normal gasoline engine has a compression ratio of about 10 to 1 (or slightly less). One problem with increased compression ratio is that fuel can ignite prematurely causing engine knock. Also during cold starts bulk of emissions are produced.While four-stroke are found on most automobiles and street legal motorcycles, two-stroke rules when it comes to off-road motorcycles, small boat and personal watercraft engines and many of the motorbikes, those serve as primary transportation in developing nations. The potential of Two- stroke engines has become more and more subject to increasing research work trying to optimize the Power-Weight ratio as well as the pollution emissions with the development of the high efficient Direct Injection System.The NOx issue notwithstanding, GDI engines get high marks in particular for the cleaner emissions. It is for this reason numerous engine companies have toiled to build two-stroke version of the gasoline direct injection engine trying to overcome issues like short circuiting, mixing, knocking, cold starting problems etc. which are otherwise produced in traditional two stroke gasoline engines with carburetors.

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II.GDI ENGINE

GDI stands for Gasoline Direct Injection. When it comes to automobile petrol engines, there are three popular types, which are –carburetor based engines, MPFI engines and GDI based engines. Gasoline Direct Injection technology has received considerable attention over the last few years as a way to significantly improve fuel efficiency without making a major shift away from the conventional internal combustion technology. In many respects, GDI technology represents a further step in the natural evolution of gasoline engine fuel systems. Starting with mechanical based carburetion, to throttle body fuel injection, through multipoint and finally sequential multipoint fuel injection, the GDI engines indicate a breakthrough in engine technology. It scores higher than the latter counterparts because of the following aspects.

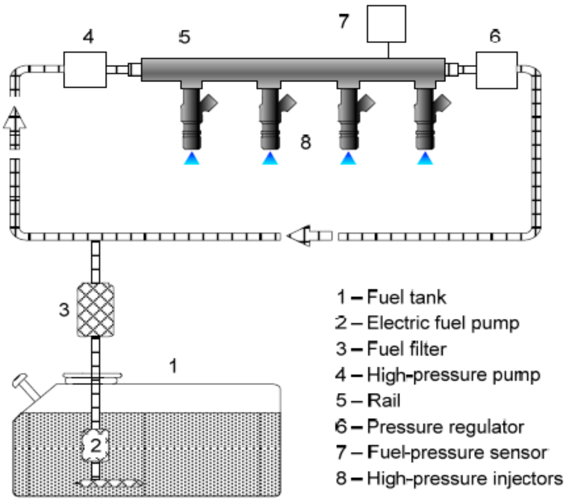

Fig.1. Fuel Supply System

The GDI technology aims at maximizing fuel economy and minimizes environmental impacts due to pollutants like HC, CO and NOx at an accessible price. It uses a lean mixture of 40 parts air to 1 part fuel, comparing to a traditional engine whose compression ratio is only 14.7:1.The lean fuel can be burned more conservatively. The fuel can be swirled directly where the combustion chamber is the hottest- means in a gasoline engine it ends up close to the spark. Thus this avoids problems due to incomplete burning of the fuel in the combustion chamber, as in the case of traditional gasoline engines. In GDI engines the ports are not used to mix the fuel and air. Thus the efficiency of airflow is increased. High compression ratio is possible due to cooling effect as the injected fuel vaporizes in the combustion chamber. This reduces charge temperature thereby reducing the likelihood of spark knock. To reduce engine knock GDI systems spray a very fine mist of fuel directly into the cylinder. This keeps the engine temperature down and reduces knocking. The increased combustion efficiency and control helps to reduce emissions particularly during cold starts during which enormous emissions are produced. It eliminates the need for a choke. Control of ignition event is very precise and results in better combustion efficiency and fuel consumption at throttle openings. No throttling losses occur in GDI engines without a throttle plate. Produces better MPG, increased Volumetric Efficiency, accurately controlled emission levels higher power output and more aggressive injection timing curves. Direct fuel injection can improve the engine efficiency by 12%. Fuel economy is increased by 10-30% over a current DI-engine, along with enhanced drivability.

III.ELECTRONIC CONTROL UNIT

The ECU controls the actuators to input signals sent by sensors. All actuators of the engine are controlled by the ECU, which regulates fuel injection functions and ignition timing, idle operating, fuel-vapor retention system, electric fuel pump and operating of the other systems. Adding this function to the ECU requires significant enrichment of its processing and memory as the engine management system must have very precise algorithms for good performance and drive ability.

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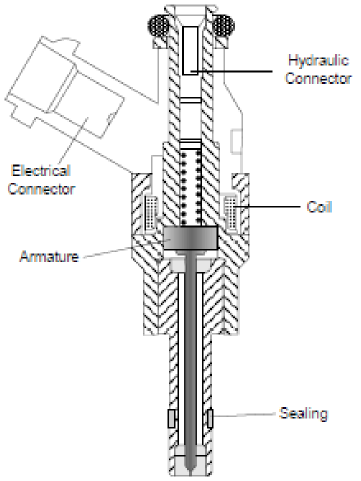

Fig.2. Schematic View of Injector

Inputs (sensors): In order to provide the correct amount of fuel for every operating condition, the engine control unit (ECU) has to monitor a huge number of input sensors. Here are just a few:

Mass Airflow Sensor: The engine load is mainly determined by a hot film Mass airflow sensor.

Throttle position Sensor: The Throttle position sensor is mounted typically on the butterfly valve throttle body, which is used to calculate the load upon the engine. It monitors the throttle valve position, which determines how much air goes into the engine, so that the fuel rate can be increased or decreased as necessary.

Coolant temperature Sensor: It helps to determine when the engine has reached its proper operating temperature.

Manifold absolute pressure Sensor: Monitors the pressure of the air in the intake manifold. The amount of air being drawn into the engine is a good indication of how much power it is producing. The more air that goes into the engine, the lower the manifold pressure, so this reading is used to gauge how much power is being produced.

Fuel injectors: A GDI injector is to supply correct amount of atomized fuel for the given engine requirement. The main requirement of a GDI application is high atomization quality.

There are wide ranges of atomization approaches but the most popular one is the Pressure-swirl atomizer, also called as Simplex atomizer. Its basic components are:

- Needle
- Swirlier
- Nozzle

The fuel flows through the needle seat passage when the needle is actuated. Before the needle reaches the needle seat passage, it is forced to flow. Liquid film will be formed on the wall of the nozzle orifice as shown in Figure No.3. This occurrence creates low-pressure region near the central axis of the orifice thus forming an air core. The purpose of a GDI injector is to supply correct amount of atomized fuel for the given engine requirement. Thus it is necessary to identify the engine in which the injector will be applied before any design work commences.

IV.TECHNIQUE TO CUTDOWN FUEL CONSUMPTION

The direct injection spark-ignition has different operating modes depending on the load and engine speed for a stable and efficient engine operation. Engines can be built to operate in two modes: in very economical stratified-charge/lean-burn mode on part-throttle and in homogeneous-charge mode when full power is required. These modes can cut the fuel consumption. Stratified mode (or Late Injection): Lean mixtures can deliver outstanding fuel economy but are very hard to ignite with an ordinary spark. This problem can be solved by aiming direct fuel injection to make the mixture richer around the sparkplug and leaner everywhere else. Such a non-uniform mixture is said to be “stratified.” It is used for lighter load running condition at constant or low speed where no acceleration is required.

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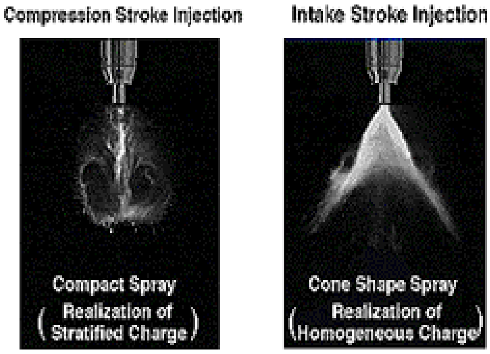

Fig.3. Injection spray

Homogeneous mode (or Early Injection): At higher loads, the mixture in the stratified mode can become too rich leading to soot formation. Also at high speeds we cannot provide sufficient stratification due to turbulence in the cylinder. So at high loads and high speeds Homogeneous Charge Compression ignition mode is used. It causes a fully mixed charge to self-ignite by compressing it together with hot exhaust gas from the previous cycle. It offers the possibility of diesel-like fuel economy on gasoline with high torque and fewer emissions. It is represented in Figure No.3.

V.EXPERIMENTAL SETUP

The lubricating oil was injected directly into the air stream leading to the crankcase. Since it was found that, at certain operating conditions, the fuel touched some portion of the cylinder wall, a small amount of lubricant was also added to the fuel to avoid piston seizure.

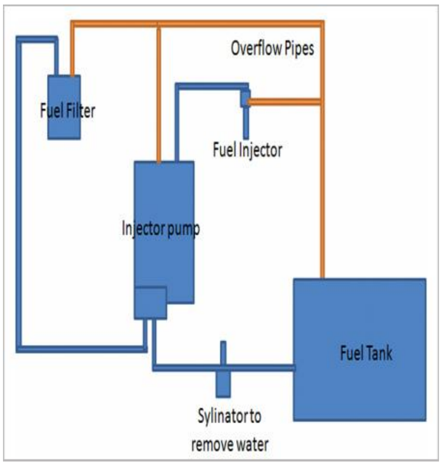

Fig.4. Block Diagram

An AVL Flue gas analyser was used to measure the exhaust hydrocarbon (n-hexane equivalent), carbon monoxide and carbon dioxide concentrations. A positive displacement pump was used to supply gasoline at a pressure of 3 to 5 bar. A hole was drilled in the cylinder head at an angle of 45 degrees to the cylinder axis, to locate the fuel injector.

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Fig.5. Experimental Setup

The direct fuel injection system is comprised of a gasoline injector, a fuel pump, a pressure regulator as shown in the Figure No.3 and Figure No.4.

VI.RESULT & DISCUSSION

EMISSION ANALYSIS

Emissions of Carbon Monoxide (CO), Carbon di-oxide (CO) And Hydro Carbon (HC) are shown in Figure 6,7,8.

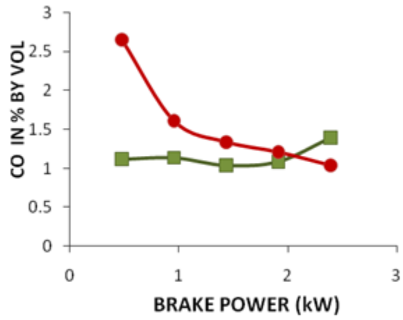

Fig.6. Brake Power Vs CO Emission

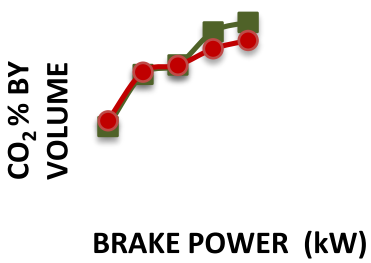

Fig.7.Brake Power Vs CO_2 Emission

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In a two-stroke engine, HC emissions will depend on how much fuel is short-circuited and also on the extent of combustion of the trapped fuel. Hence, in the case of retarded injection timings (even through a better trapping of the injected fuel can be expected) the HC levels are higher due to poor combustion because of insufficient time available for mixture formation.

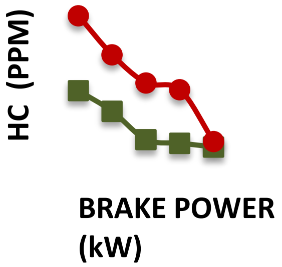

Fig.8. Brake Power Vs HC Emission

The CO level with direct injection is higher than with manifold injection because the trapped air and fuel mixture is richer. With lean mixtures where almost all of the trapped fuel can be expected to burn as more fuel is trapped and the trapped mixture becomes richer.

EFFIENCY GRAPH

SPFC of GDI Engine is 8.66% reduced, compared with Conventional type. The advantage of low specific fuel consumption is, it increases the mileage and the variation in specific fuel consumption is show in Figure 9. The variations in the indicated power are shown in the Figure 10. Mechanical Efficiency of GDI Engine is 13.5% better compared with the Conventional type. The variations is shown in Figure 11 and the Brake thermal Efficiency of GDI Engine is 11.6% better compared with the Conventional type as shown in Figure 12. Indicated thermal Efficiency of GDI Engine is 12.02% better compared with the Conventional type as shown in Figure 12.

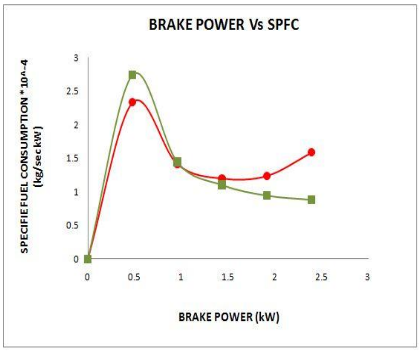

Fig.9.Brake Power Vs Specific Fuel Conception

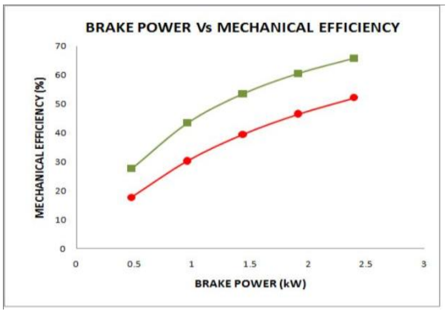

Fig.10.Brake Power Vs Mechanical Efficiency

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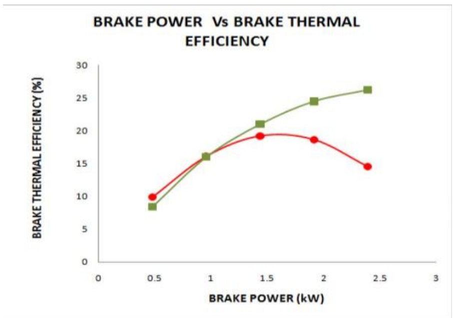

Fig.11. Brake Power Vs Thermal Efficiency

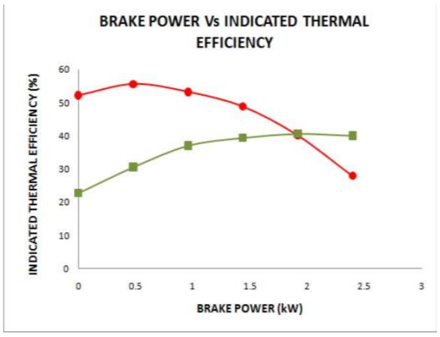

Fig.12. Brake Power Vs Indicated Thermal Efficiency

VII.CONCLUSION

Engine performance compared to conventional engines of a comparable size, the GDI engine provides approximately 10% greater outputs at all speed. In high output mode, GDI engines provide outstanding acceleration. Frequent operation in stratified mode reduces CO2 production by nearly 20% and also improves the brake specific fuel consumption. Smooth transition between operating modes is achieved. The gasoline direct injection engine provides improved torque and fulfils future emission requirements. GDI is simple to implement and can be retrofitted in two-stroke engines. Fuel consumption was reduced by 15-20%. Higher torque 5-10% was produced. Also good and spontaneous throttle response behavior was obtained. Best features of all the above are expected to increase more in short term.

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