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PERFORMANCE INCREASE AND EMISSION REDUCTION BY WATER INJECTION IN SINGLE CYLINDER S.I. ENGINE

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ABSTRACT

This paper presents the result for liquid water is injected in an atomized state into the cylinder during the angle of 8(degree) before TDC. Employing water into the cylinder in an atomized state during the suction stroke., so that during compression, the atomized water inside the cylinder ,absorbs the heat and converts into vapor. This reduces the internal heat and the water absorbs the exhaust gas. While the exhaust gas along with the water comes out, cannot react with the atmosphere directly. Hence the pollution decreases. Using Water injection during the expansion stroke revealed two stages of the in-cylinder pressure, the first stage involved a decrease in pressure by heat absorption and the second stage involved an increase in the pressure as a result of an increase in the steam volume via expansion. The percentage decrease of in-cylinder pressure was 2.7% during the first stage and a 2.5% pressure increase during the second stage.

Keywords: *Water injector, Fuel pump,fuel injector manifold*

INTRODUCTION

In an internal combustion engines, water injection also known as Anti-detonant injection, can spray water into the incoming air on fuel-air mixture or directly into the cylinder to cool certain parts of the cool certain parts of induction system where "HOT POINTS" could produce premature ignition. In jet engines thrust at low speeds and at take off.

1.1 PURPOSE OF WATER INJECTION

The main purpose of the thesis is to evaluate the effects of water injection in several engine operating points, where the probability of knock is high. The objective is to develop a model that can capture the water injection effects on cylinder pressure and combustion. It is intended to display effects on ignition timing so that better control strategies can be developed. Injection strategies such as timing and amount/frequency are to be included in the model. Several questions that define the problem in this thesis are displayed below.
Once the thesis is finished, these questions should be answered.

- Can the engine be more efficient using water injection?
- Which injection strategy is preferred in different operating points?
- How can the system be modeled?

Hopefully, by answering these questions, it can be easier to conclude whether or not water injection is a technology to invest in.

1.2 FUEL INJECTION

Fuel injection is the introduction of fuel in an internal combustion engine, most commonly automotive engines, by the means of an injector. On petrol engines, fuel injection replaced carburetors from the 1980s onward. The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel through a small nozzle under high pressure, while a carburetor relies on suction created by intake air accelerated through a Venturitube to draw the fuel into the airstream.

The invention of mechanical injection for gasoline-fueled aviation engines was by the French inventor of the V8 engine configuration, Leon Levavasseur in 1902. Levavasseur designed the original Antoinette firm's series of V-form aircraft engines, starting with the Antoinette 8Vto be used by the aircraft the Antoinette firm built that Levavasseur also designed, flown from 1906 to the firm's demise in 1910, with the world's first V16 engine, using Levavasseur's port injection and producing around 100 hp (75 kW; 101 PS) flying an Antoinette VII monoplane in 1907.

The first post-World War I example of direct gasoline injection was on the Hesselman engine invented by Swedish engineer Jonas Hesselman in 1925. Hesselman engines used the ultra-lean-burn principle and injected the fuel in the end of the compression stroke and then ignited it with a spark plug, it was often started on gasoline and then switched over to run on diesel or kerosene. The Hesselman engine was a low compression design constructed to run on heavy fuel oils.

Direct gasoline injection was applied during the Second World War to almost all higher-output production aircraft powerplants made in Germany (the widely used BMW 801 radial, and the popular inverted inline V12 Daimler-Benz DB 601, DB 603, and DB 605, along with the similar Junkers Jumo 210G, Jumo 211, and Jumo 213, starting as early as 1937 for both the Jumo 210G and DB 601), the Soviet Union (Shvetsov ASh-82FN radial, 1943, Chemical Automatics Design Bureau - KB Khimavtomatika).

Immediately following the war, hot rodder Stuart Hilborn started to offer mechanical injection for race cars, salt cars, and midget racers,[9] well-known and easily distinguishable because of their prominent velocity stacks projecting upwards from the engines on which they were used. The first automotive direct injection system used to run on gasoline was developed by Bosch, and was introduced by Goliath for their Goliath GP700 automobile, and Gutbrod in 1952. This was basically a specially lubricated high-pressure diesel direct-injection pump of the type that is governed by the vacuum behind an intake throttle valve. (Modern diesels only change the amount of fuel injected to vary output; there is no throttle.) This system used a normal gasoline fuel pump, to provide fuel to a mechanically driven injection pump, which had separate plungers per injector to deliver a very high injection pressure directly into the combustion chamber. The 1954 Mercedes-Benz W196 Formula 1 racing car engine used Bosch direct injection derived from wartime aircraft engines. Following this racetrack success, the 1955 Mercedes-Benz 300SL, the first production sports car to use fuel injection, used direct injection. The 1955 Mercedes-Benz 300SLR, in which Stirling Moss drove to victory in the 1955 Mille Miglia and Pierre Levegh crashed and died in the 1955 Le Mans disaster, had an engine developed from the W196 engine. The Bosch fuel injectors were placed into the bores on the cylinder wall used by the spark plugs in other Mercedes-Benz six-cylinder engines (the spark plugs were relocated to the cylinder head). Later, more mainstream applications of fuel injection favored the less-expensive indirect injection methods. Chevrolet introduced a mechanical fuel injection option, made by General Motors' Rochester Products Division, for its 283 V8 engine in 1956 (1957 U.S. model year). This system directed the inducted engine air across a "spoon shaped" plunger that moved in proportion to the air volume.

The plunger connected to the fuel metering system that mechanically dispensed fuel to the cylinders via distribution tubes. This system was not a "pulse" or intermittent injection, but rather a constant flow system, metering fuel to all cylinders simultaneously from a central "spider" of injection lines. The fuel meter adjusted the amount of flow according to engine speed and load, and included a fuel reservoir, which was similar to a carburetor's float chamber. With its own high-pressure fuel pump driven by a cable from the distributor to the fuel meter, the system supplied the necessary pressure for injection. This was a "port" injection where the injectors are located in the intake manifold, very near the intake valve.

1.2 Electronic Injection

Because mechanical injection systems have limited adjustments to develop the optimal amount of fuel into an engine that needs to operate under a variety of different conditions (such as when starting, the engine's speed and load, atmospheric and engine temperatures, altitude, ignition timing, etc.) electronic fuel injection (EFI) systems were developed that relied on numerous sensors and controls. When working together, these electronic components can sense variations and the main system computes the appropriate amount of fuel needed to achieve better engine performance based on a stored "map" of optimal settings for given requirements in 1953, the Bendix Corporation began exploring the idea of an electronic fuel injection system as a way eliminate the well known problems of traditional carburetors.

The first commercial EFI system was the "Electrojector" developed by Bendix and was offered by American Motors Corporation (AMC) in 1957. The Rambler Rebel, showcased AMC's new 327 cu in (5.4 L) engine. The Electrojector was an option and rated at 288 bhp (214.8 kW). The EFI produced peak torque 500 rpm lower than the equivalent carburetored engine The Rebel Owner Manual described the design and operation of the new system. An electronic control control box located under the dashboard uses information from various sensors for engine starting, idling, and acceleration requirements to determine optimal timing of the fuel charge by electrically actuating the injectors. According to AMC, the price would be significantly less than Chevrolet's mechanical fuel injection option. Electrojector's teething problems meant only pre-production cars were so equipped: thus, very few cars so equipped were ever sold and none were made available to the public. The EFI system in the Rambler ran fine in warm weather, but suffered hard starting in cooler temperatures.

Chrysler offered Electrojector on the 1958 Chrysler 300D, DeSoto Adventurer, Dodge D-500, and Plymouth Fury, arguably the first series-production cars equipped with an EFI system. It was built Bendix The early electronic components were not equal to the rigors of underhood service, however, and were too slow to keep up with the demands of "on the fly" engine control. Most of the 35 vehicles originally so equipped were field-retrofitted with 4-barrel carburetors. The Electrojector patents were subsequently sold to Bosch.

1.3 CYLINDER PRESSURE MODELING

To model the effects of water injection, it is necessary to have a model of the in-cylinder pressure. An analytic cylinder pressure model is developed in Eriksson and Andersson . The model consists of four parts, one of which is the gas exchange phase, where the pressures are approximated to be equal to the intake/exhaust manifold pressures. The compression and expansion processes are both modeled as polytropic processes, providing a pressure and temperature trace.

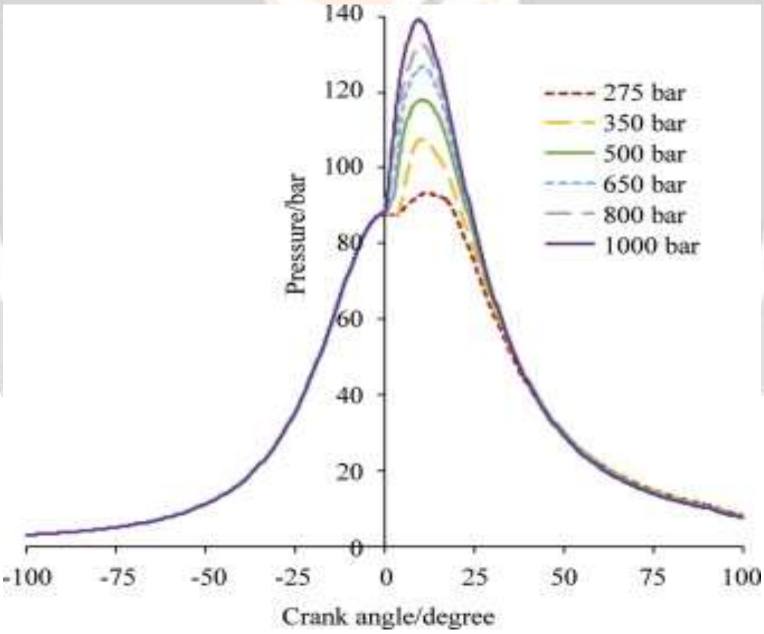


Fig 1.3 Cylinder Pressure Model

The pressure traces from these two are subsequently interpolated to create the combustion part using the Vibe function. The initial pressure during the 3 4 2 Related Research compression stroke can be approximated as the intake manifold pressure at IVC. However, if the approximation does not give sufficiently accurate results, a model could be used instead. Both papers, Lindström and Hashemzadeh Nayeri, give an example of how the intake manifold pressure can be modeled. More work has been done, investigating how cylinder pressure in SI Engines can be estimated.

For example, Shiao and Moskwa uses a single-zone dynamic model where the principal assumptions are that the temperature, pressure and cylinder charge are all uniform within the cylinders

2. KNOCK

In order to understand the effects of knock, one has to know what knock is and how it happens. When the spark ignites the fuel mixture in the cylinder, it starts to burn in a controlled detonation. The flame starts at the ignition point and spreads out towards the cylinder walls. The detonation leads to an increase in the cylinder pressure and temperature. If the temperature and pressure is high enough, the unburned gas can ignite by itself, creating a second uncontrolled detonation in the cylinder. These uncontrolled detonations release energy much more rapid than a normal ignition, see Eriksson and Nielsen, which can result in severe engine damage. To prevent knock from occurring, the ignition/combustion is postponed. This is executed with help of a limit on the spark angle, called Detonation Border Limit (DBL). The limit prevents the engine from running in operating points where knock is more probable to occur, for example at low speeds and high loads. Worm et al. describes other methods to prevent knock, one of which is to use fuel enrichment since it lowers the temperature. One could also, for example, decrease the compression ratio, but these actions have a negative impact on the engine efficiency. Another possibility is to use a high octane fuel, but this is more expensive and a severe limitation to the customers.

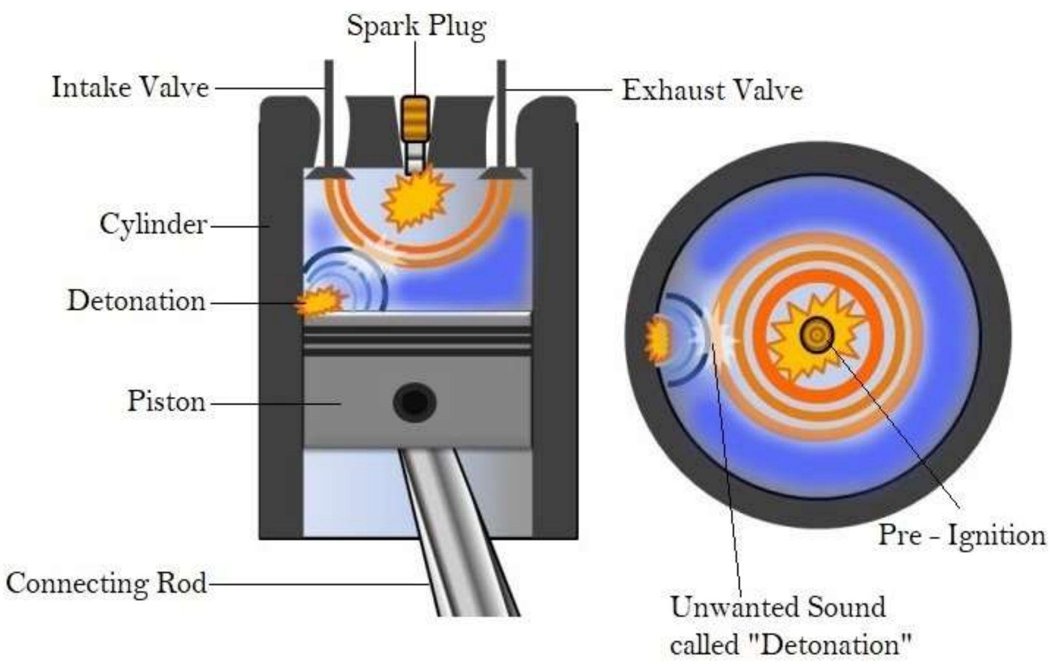


Fig 1.4 Knocking

Water has a high enthalpy of vaporization and when it is injected into the cylinder, it works as a coolant, see Rohit et al. Experiments have shown that the pressure in the combustion chamber is reduced with water injection, together with the exhaust temperatures, which means that the risk of engine knock is reduced, see Iacobacci et al., Lezhong et al., Hoppe et al., and Worm et al. Research on how to analytically describe knock is carried out in e.g. Eriksson and Sivertsson, Heywood, and Ganestam. A semi two-zone model can be used to track the burned and unburned temperatures in the cylinder chambers. The unburned temperature is included in the Arrhenius function, to create the knock index in equation. This integral is used in the papers above as a knock model.

3. WATER INJECTION

There are several experiments performed on engines with water injection that result in several interesting documented effects. However, there are differences in experimental setup and approach used in each experiment, and it is uncertain whether all of these effects will be seen with the hardware used in this thesis. Several technical reports have shown similar results when it comes to the effects on engine out emissions. The NO*x* emissions are reduced, HC emissions are increased and the CO and CO2 emissions are similar, see Lanzafame , Lanzafame and Brusca , Rohit et al., Iacobacci et al., Mingrui et al., and Hoppe et al., for examples.

When it comes to the NO*x*, studies have shown that, besides the amount of water that is injected, also the timing of the injection affects how much reduction of the emissions are achieved. The earlier the water is injected, the less water is needed. As seen in Rohit et al., if the water is injected at 340 degrees before TDC (BTDC), a water-fuel ratio (defined as water mass divided by fuel mass) of 40% is needed to reduce the NO concentration from 3.0 to 0.5 ppm. If the water is injected at 45˚ BTDC, a 100% of the fuel mass is needed. The authors have shown that the optimum SOI is 120˚ BTDC. With a 50% water-fuel ratio, this setting gives an efficiency increase of 3%.

The major reason for this is that MFB50 can be moved closer to the optimum angle of 8˚ ATDC. In Bhagat et al., investigations show how injection timing affects the vaporization of the water are carried out using a CFD model. It is found that earlier injection leads to better vaporization and decreased tendency of wall wetting formation. The experiments are performed to analyze the emission effects from water injection temperature. It is shown that a higher injection temperature leads to higher NOx emissions and lower HC emissions. The water acts like a coolant, thus reducing the risk of knock since the temperature of the unburned gas is lowered. This enables the ignition to be closer to MBT and thereby reach a higher efficiency.

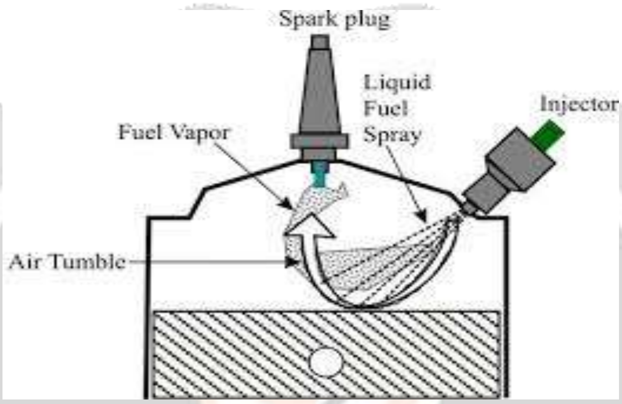


Fig 1.5 Water injection

As seen in Iacobacci et al., Lezhong et al., and Hoppe et al., only injecting water lowers the indicated mean effective pressure (IMEP). But with an increased spark advance (ignition earlier BTDC), the authors have shown that the IMEP can increase by 1.5 bar using a 30% water-fuel ratio. This can allow the engines to have a higher compression ratio and higher boost pressure, Related Research leading to more power output.

It is also shown that the turbine inlet temperature is lowered, especially at higher engine speeds, because of the increase in the heat capacity of the charge in the cylinder, see Iacobacci et al., . Moreover, the cooling of the air-fuel mixture leads to a more dense gas and hence more mass is trapped in the cylinder. With more air mass, more fuel mass can be burned leading to a higher power output, see Rohit et al., Experiments from Worm et al. show that the exhaust temperature can be decreased as much as 200˚C with water injection, which can protect the turbo from wear. Moreover, in Boretti it is stated that water injection reduces the combustion chamber temperature and the inlet turbine temperature, resulting in higher power densities and better fuel conversion efficiencies. The author claims that the favorable combinations of boost pressure, spark advance and compression ratio are not possible with other technologies.

4. EFFECTS OF WATER INJECTION

In a piston engine, the initial injection of water cools the fuel-air mixture significantly, which increases its density and hence the amount of mixture that enters the cylinder. The water (if in small liquid droplets) may absorb heat (and lower the pressure) as the charge is compressed, thus reducing compression work. An additional effect comes later during combustion when the water absorbs large amounts of heat as it vaporizes, reducing peak temperature and resultant NOx formation, and reducing the amount of heat energy absorbed into the cylinder walls. This also converts part of combustion energy from the form of heat to the form of pressure. As the water droplets vaporize by absorbing heat, they turn to high pressure steam. The alcohol in the mixture burns, but is also much more resistant to detonation than gasoline. The net result is a higher octane charge that supports very high compression ratios or significant forced induction pressures before onset of detonation.

METHODOLOGY

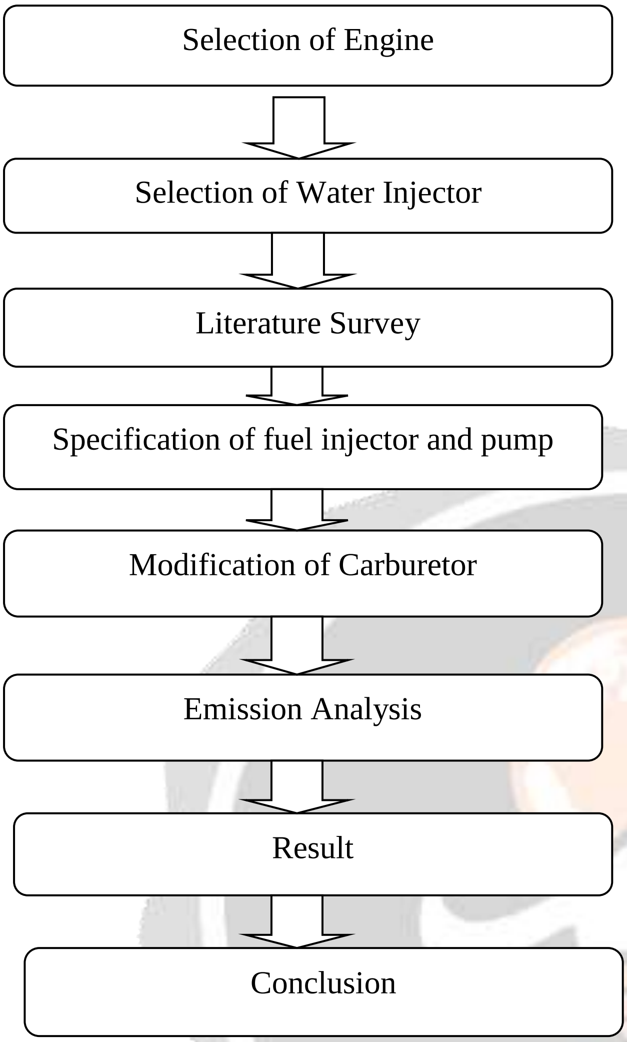


Fig 4 Methodology Flow chart

4.1 WORKING PRINCIPLE

The principal used here is mainly the absorption of heat by the atomized state and convert into vapor inside the combustion chamber. The pulsar 220 air/fuel manifold which is having the injector port is connected in the place of manifold of discover135 dts-i. The injector is fixed in the injector port and the positive wire is connected directly to the ignition coil input wire and the negative wire is fixed in a switch which has the other end in the negative of battery. The fuel pump is fixed near the fuel tank in a water tank. The fuel pump is connected with the positive and negative of battery. A three way valve is fixed with the pump. The first and second way of valve passes water to the injector. The valve is in the t shape, so from the another way the water circulates from the water pump to the water tank. The process starts with the ON of ignition switch. When the ignition switch is ON, the water pump starts pumping the water. Till the injector gets ON the water will circulate continuously. When the vehicle moves continuously for 3kms,the switch of the injector should ON manually. The input of the ignition coil gets power, only when the spark is needed. The ignition coil steps up the 12v power to 20000v. As the injector is connected in the input of the ignition coil whenever, the input of ignition coil gets power, the injector will spray the water in the atomized state into the manifold where air/fuel mixture flows from carburetor to the combustion chamber. When the piston sucks the water in the atomized state along with the air/fuel, mixture due to the internal heat of the engine, the water is converted into vapor and absorbs the pollutant gases from the fourth stroke of the combustion chamber. Due to this absorption of gas and coming out from the exhaust, the pollutant gas cannot react directly with the atmosphere and cannot make pollution in the atmosphere. As the water injected in the combustion chamber, a little amount of heat gets absorbed, due to this the large amount of heat in engine is decreased and thus results in reduction of knocking .As the water absorbs the pollutants from the combustion chamber, there will be no carbon deposit on the piston, this increases the lifetime of the piston. Due to this water injection, the efficiency and performance of the engine gets increased. Due to the injection of water the mileage of the engine will be decreased. As the reduction of nix, knocking and internal heat, the combustion of the fuel will be made completely. Hence the motion of the vehicle distance will be increased. the engine life is increased and the piston life also gets improved, as the reduction of carbon deposit by water injection.

5. INJECTOR LAYOUT

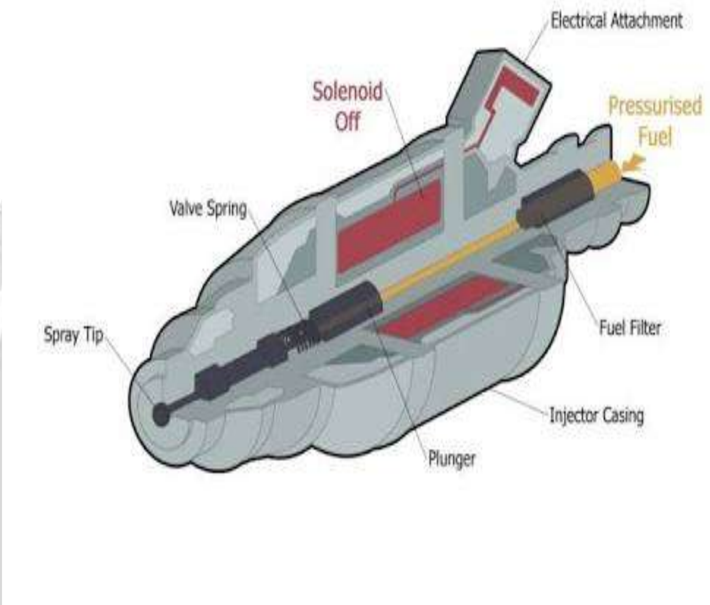


Fig 5.1 Injector Layout

6. BEFORE WATER INJECTION

Serial No. 14817

FORM (Computerised Pollution under Control Certificate/Petrol/CNG/LPG)
(See Rule 116-B (10) (C) (Authorised by the Transport Department)

Transport Dept. Seal

SRI VIGNESH EMISSION TESTING CENTRE
No. 64, Old State Bank Colony Road, West Tambaram, Chennai-600 045.
Cell No. 99520 17400 Cell No. 98411 42821
Centre Code : TN 22 / 012 Authorisation Validity : 10-06-2020

I.D. Number : G201918832
Vehicle Number : TN 07 BD 9280
Month & Year of Manufacture : 04 / 2009
BS II Complaint : No
Odometer Reading (Kms) : 0
Test : IDLING

Type of Vehicle : DISCOVER
Type of Engine : BAJAJ
Maker's Name : 4 Stroke
Maker's Class : 2 Wheeler

Fuel : PETROL
Date : 08 Mar 2019
Time : 2:37:37 PM

PARAMETER	Regulation Limit	Actual
CO (% by Vol)	3.5	1.75
HC (PPM)	4500	63
LAMBDA		

* See Permissible Limits at the back of form

Validity : 6 Months Certificate Valid Upto 07 Sep 2019

Name of the Driver / Owner :

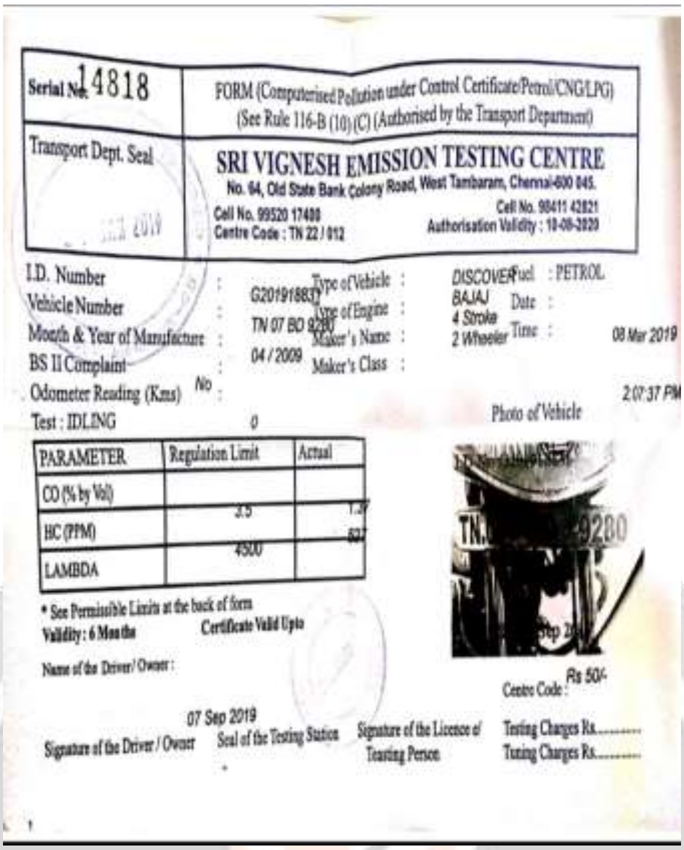
Photo of Vehicle

Centre Code : Rs 50/-

Signature of the Driver / Owner Seal of the Testing Station Signature of the Licence e/ Testing Person

Testing Charges Rs.______
Tuning Charges Rs.______

Fig 6.1 Before water injection



Serial No. 14818

FORM (Computerised Pollution under Control Certificate/Petrol/CNG/LPG)
(See Rule 116-B (10) (C) (Authorised by the Transport Department)

Transport Dept. Seal

SRI VIGNESH EMISSION TESTING CENTRE
No. 64, Old State Bank Colony Road, West Tambaram, Chennai-600 045.
Cell No. 99520 17400 Cell No. 98411 42821
Centre Code : TN 22 / 012 Authorisation Validity : 10-08-2020

I.D. Number : G201918837
Vehicle Number : TN 07 BO 9280
Month & Year of Manufacture : 04 / 2009
BS II Complaint : No
Odometer Reading (Kms) : 0
Test : IDLING

Type of Vehicle : DISCOVER
Type of Engine : BAJAJ 4 Stroke
Maker's Name : 2 Wheeler
Maker's Class :

Fuel : PETROL
Date : 08 Mar 2019
Time : 2:07:37 PM

Photo of Vehicle

PARAMETER	Regulation Limit	Actual
CO (% by Vol)	3.5	[illegible]
HC (PPM)	4500	627
LAMBDA		

* See Permissible Limits at the back of form
Validity : 6 Months Certificate Valid Upto 07 Sep 2019

Name of the Driver/ Owner :

Centre Code : Rs 50/-

Signature of the Driver / Owner Seal of the Testing Station Signature of the Licence of Testing Person Testing Charges Rs......... Tuning Charges Rs.........

Fig 6.2 After water injection

7.CONCLUSION

The use of water in the combustion process of internal combustion diesel engine can be a part of solution to the problem of pollution control and fossil fuel depletion. Using water injector emulsion, NOx and Particulate matters effects can be effectively controlled in the engines. The mechanism of micro explosion of the droplets is understood from the theoretical view to certain extent. A micro explosion in a water injector engine and have been verified experimentally.

Experiment investigations confirms the advantages of water injection emulsion technique in reducing NOx and Particulate matter emissions. Besides the water injection emulsion technique, the fumigation has also been investigated. The available results show a significant reduction of NOx and Particulate matter emissions in the system using this method. Compared to emulsion a less number of studies are followed in fumigation. The direct water injection method has also been investigated to emission and performance parameters of the water injector engine. Results shows a significant reduction of NOx and Particulate matter emissions in this system using the method.

- The exhaust gas temperature decreases as the mass of water to fuel ratio and its increases.
- In the exhaust gas the level of carbon monoxide decreases as the mass of a water to fuel ratio increases.
- The consumption of fuel decreases as the mass of the water to fuel ratio its increase.

8.BEFORE MODIFICATION TEST

Fig 8.1 Before modification test

8.2 AFTER MODIFICATION TEST

Fig 8.3 After modification test

9. REFERRED JOURNALS

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2. S. Breda et al. "Effects on knock intensity and specific fuel consumption of port water/methanol injection in a turbocharged GDI engine" Vol.2, Pp: 96–102,(2015).
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