Simultaneous Attainment of Low Fuel Consumption, High Output Power and Low Exhaust Emissions in a Preheated Fuel Of 350cc Si Engine

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Abstract: This paper describes simultaneous attainment in improving fuel consumption, output and reducing HC and CO Emissions with a preheated direct injection SI engine. In the present work, many modifications were made for the developed direct fuel injection system. The performance of the 350 cc Bullet engine under all modification is compared with an objective to achieve better power and emission characteristics with the latter. The complete atomization of fuel is necessary to achieve proper mixing that is, the mixture can be homogenous. To achieve this the atomization of fuel is done by using preheating the fuel before it is ignited by the nozzle thus the fuel preheated atomizes well compared to cooler fuel. The present work gives way for improvement of performance of the engine. For motorcycle application, a central injection, spray guided DI combustion may offer the characteristics required to meet many of challenges of this difficult application. To demonstrate the potential of such an application, a 350cc engine has been developed using an air-assist DI spray guided significant fuel economy improvements when compared to the baseline carbureted engine, as well as potential to meet current and future emission legislations with a variety of system configurations.

Key words: petrol injection, heat exchanger, carburetion, preheater, fuel injector, fuel pump

INTRODUCTION

1 Fuel injection

Fuel injection is a system for admitting fuel into an internal combustion engine. It has become the primary fuel delivery system used in automotive engines, having replaced carburetors during the 1980s and 1990s. A variety of injection systems have existed since the earliest usage of the internal combustion engine. The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburetor relies on suction created by intake air rushing through a venturi to draw the fuel into the air stream. Modern fuel injection systems are designed specifically for the type of fuel being used. Some systems are designed for multiple grades of fuel (using sensors to adapt the tuning for the fuel currently used). Most fuel injection systems are for gasoline or diesel applications.

1.1 Objectives

The functional objectives for fuel injection systems can vary. All share the central task of supplying fuel to the combustion process, but it is a design decision how a particular system is optimized. There are several competing objectives such as:

- Power output
- Fuel efficiency
- Emissions performance
- Ability to accommodate alternative fuels
- Reliability
- Drivability and smooth operation
- Initial cost
- Maintenance cost
- Diagnostic capability

1.2 CARBURETOR

The carburetor works on Bernoulli's principle: the faster air moves, the lower its static pressure, and the higher its dynamic pressure. The throttle (accelerator) linkage does not directly control the flow of liquid fuel. Instead, it actuates carburetor mechanisms which meter the flow of air being pulled into the engine. The speed of this flow, and therefore its pressure, determines the amount of fuel drawn into the air stream.

WORKING:

In an engine, carburetion combines the proper ratio of oxygen with a gaseous form of a fossil fuel, like natural gas or gasoline, so it can combust. Internal combustion engines run by igniting fuel that has been sprayed into a fine vapor and mixed with air. This mixture, called an emulsion, will burn with the right amount of energy to fuel the engine. Carburetion usually involves all these stages, from vaporizing the gasoline to letting in the air and finally moving the mixture to where it can be combusted. Carburetion is responsible for allowing an engine to perform at an optimal level whether it is starting, running at full throttle, or idling. Any combustion engine, such as on a lawnmower, chainsaw, or automobile, must utilize some form of carburetion. If there is too much fuel or too little oxygen, the engine runs "rich" and wastes fuel, produces smoke, creates too much heat, or ruins parts of the engine. If there is too little fuel or too much air, the engine runs "lean" and might sputter, stop, or cause engine damage. The process of carburetion usually takes place inside a carburetor, but it can even be demonstrated with a home chemistry set. In a carburetor, there must be a central mixing chamber where the air will meet the fuel. One opening, a needle valve, pushes fuel through such a tiny hole that it sprays into that chamber in fine droplets. The other opening, a vacuum or suction valve, uses air pressure to control how much air enters the chamber, called metering. The atomized gasoline, suspended in the full volume of air, exits through a wide tube to another chamber where a spark will ignite it.

1.3 SUPERSESSION OF CARBURETOR

The ultimate combustion goal is to match each molecule of fuel with a corresponding number of molecules of oxygen so that neither has any molecules remaining after combustion in the engine and catalytic converter. Such a balanced condition is known as stoichiometry. Extensive carburetor modifications and complexities were needed to approach stoichiometric engine operation in order to comply with increasingly-strict exhaust emission regulations of the 1970s and 1980s. This increase in complexity gradually eroded and then reversed the simplicity, cost, and packaging advantages carburetors had traditionally offered over fuel injection systems. There are three primary types of toxic emissions from an internal combustion engine: Carbon monoxide (CO), unburnthydrocarbons (HC), and oxides of nitrogen (NOx). CO and HC result from incomplete combustion. [6] of fuel due to insufficient oxygen in the combustion chamber. NOx, in contrast, results from excessive oxygen in the combustion chamber. The opposite causes of these pollutants make it difficult to control all three simultaneously. Once the permissible emission levels dropped below a certain point, catalytic treatment of these three main pollutants became necessary. This required a particularly large increase in fuel metering accuracy and precision, for simultaneous catalysis of all three pollutants requires that the fuel/air mixture be held within a very narrow range of stoichiometry. The open loop fuel injection systems had already improved cylinder-to-cylinder fuel distribution and engine operation over a wide temperature range, but did not offer sufficient fuel/air mixture control to enable effective exhaust catalysis. Closed loop fuel injection systems improved the air/fuel mixture control with an exhaust gas oxygen sensor. The O2 sensor is mounted in the exhaust system upstream of the catalytic converter, and enables the engine management computer to determine and adjust the air/fuel ratio precisely and quickly. Fuel injection systems have evolved significantly since the mid-1980s. Current systems provide an accurate, reliable and cost-effective method of metering fuel and providing maximum engine efficiency with clean exhaust emissions, which is why EFI systems have replaced carburetors in the marketplace. EFI is becoming more reliable and less expensive through widespread usage. At the same time, carburetors are becoming less available, and more expensive. Even marine applications are adopting EFI as reliability improves. Virtually all internal combustion engines, including motorcycles, off-road vehicles, and outdoor power equipment, may eventually use some form of fuel injection.

1.4 Heat Exchanger:

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact.[1] There are two primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat from the heat (transfer) medium. See countercurrent exchange. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. The driving temperature across the heat transfer surface varies with position, but an appropriate mean temperature can be defined. In most simple systems this is the log mean temperature difference (LMTD).

1.4.1 Types of Heat Exchangers:

Shell and tube heat exchanger, Plate heat exchanger, Adiabatic wheel heat exchange Plate fin heat exchanger, Fluid heat exchangers, Waste heat recovery units, Dynamic scraped surface heat exchanger. The heat exchanger we have designed is waste heat recovery units. A Waste Heat Recovery Unit (WHRU) is a heat exchanger that recovers heat from a hot gas stream while transferring it to a working medium, typically water or oils. The hot gas stream can be the exhaust gas from a gas turbine or a diesel engine or a waste gas from industry or refinery.

Fig 1: Heat exchanger

METHODOLOGY

In order to develop the fuel injection system, 4 stroke 350cc petrol engine is considered. In order to install the fuel injection system to this engine, a various options were considered as to take the power from the camshaft and also from the crankshaft. Taking power from the crankshaft was found to be more suitable and convenient from the alternator side of the engine. The fuel pump has to deliver high pressure fuel once during each two revolutions of crankshaft, for this purpose a speed reduction drive has been fabricated and power for this drive is taken from the crankshaft directly. A suitable camshaft has been identified which has a cam giving a rise of 8mm and which is found to be suitable to drive the fuel pump. The fuel pump is mounted identifying suitable location for the flat faced follower to maintain contact with the cam. The entire assembly has been installed to the engine and is found to be working satisfactorily. In regard to the installation of atomizer or fuel injector, the existing hole meant for decompression valve has been used to mount the fuel injector in the engine head. The spark plug meant for ignition has been located in its respective hole. The spark plug is oriented in such a way that it can easily fire the fuel, injected by the atomizer.

2.1 Definition:

The purpose of the project is to atomize the fuel by preheating the pressure pipe of fuel inlet .There were many option the   laid down for the purpose. The selection of the best suitable method was the challenge. Here we had option of preheating the fuel with the following aid: Electrical heater, Water bath, heating from exhaust gas. We selected the last option of preheating with exhaust gas as it does not cause any load on the engine and heat from the exhaust gas can be used to heat the fuel. The option we selected was optimum and we started work on it. The system we were designing was waste heat recovery system.

2.2. Development of heat exchanger:

The development of heat exchanger was from the concept of using waste heat from exhaust to heat the fuel. This was achieved by the waste heat recovery type of heat exchanger. Here we designed a tubular cross flow heat exchanger. The exhaust gas was made to flow on the high pressure pipe of fuel injection system. The outer pipe surrounded the inner pipe and the gas flow was controlled and directed by a valve and the exhaust gas was made flow out. Thus the system preheats the fuel before entering into the cylinder.

2.3 Uses of Preheat:

Atomization of fuel.Homogeneous mixture formation. Complete combustion. Avoids dripping of fuel at nozzle Avoids knocking of the engine   By avoiding rich soot formation, Avoiding deposit of fuel on cylinder walls and on edges of the piston rings. Reduces pollution, Increases the efficiency, Gives high powered can be used in colder climate condition. The only problem faced by the system is vapor lock. To avoid vapor locking, the fuel should be heated within a temperature limit of 40 degree Celsius.

2.4 Using Fuel Injection System:

The effect of the injector mounting angle on the quantity of fuel adhering to the cylinder head, piston crown and cylinder wall for fuel injection during the intake stroke. In the direct injection gasoline engine used in

this work, the results indicate that the amount of fuel adhering to the cylinder wall, which is estimated to be a cause of cylinder wall scuffing, was reduced when the fuel injector mounting angle was greater than 35 deg.On the other hand, the quantity fuel adhering to the piston crown, which is a cause of smoke formation, increased.In this system, the fuel is sprayed directly into the chamber using atomizer. Receives the pressurized fuel from the pump, which is driven by the cam shaft in turn by the reduction gears. The filter is connected in between the fuel tank and the fuel pump, which traps any foreign particles. Through methodical analysis the power of the fuel injection pump has been drawn from the crank shaft. At the alternator end of the engine reduction drive has been designed and a suitable cam shaft is used to drive the fuel injection pump. The fuel injection pump is mounted on the transmission box ensuring proper contact of the pump follower with the injector is located in the hole meant for the spark plug and the spark plug is suitably oriented by placing it through the hole meant for decompression valve. In this manner a fuel injection system has been successfully installed in this engine. Thisengine also has a conventional carburetor, in order to compare the performance of t conventional carburetor with that of fuel injection system.

2.5 DESIGN:

The design of the heat exchanger is a concept derived by industrial waste heat recovery unit. The exchanger was designed by the simple tubular cross flow heat exchanger. The two pipes are: 1. Outer exhaust by pass 2. Inner pressure pipe of fuel inlet. The outer pipe is welded over the inner pipe and the exhaust gas is made to flow over the inner pressure pipe line.

Location: The heat exchanger is located on the high pressure pipe of fuel pump. The location was selected to avoid any losses of fuel due to leakages. The heating of pressure pipe gives an advantage of pressurized delivery of the fuel without affecting it from vapor lock. Fabrication: The heat exchanger is fabricated by the process of gas welding. The bypass of exhaust pipe is made to run over the high pressure pipe line. The exhaust by pass pipe is welded to the high pressure pipe line.

Calculation:The temperature readings were taken to note the heat transfer. The initial temperature of fuel inlet was taken by the fuel tank; the preheated temperature was noted by collecting the fuel at nozzle outlet. The inlet exhaust gas at by pass was taken and the temperature at the outlet of bypass exhaust gas was heated by use of thermometer. The following temperature was obtained: Initial temperature of fuel 27°C, Pre heated fuel temperature 38°CInlet of bypass exhaust80°C, Outlet of bypass exhaust   65°c

2.6 Experimental Setup:

The experimental setup shown in fig.2 consists of a 350cc four stroke single cylinder petrol engine and a hydraulic dynamometer for loading and to measure the brake power of the engine for different loads. A mileage tank is connected to measure the fuel consumption of the engine. The performance test on the engine is carried out by the following ways:.Using conventional carburetor.Using fuel injection system.By preheating the fuel. In conventional carburetor system the engine receives the air fuel mixture through the conventional carburetor.
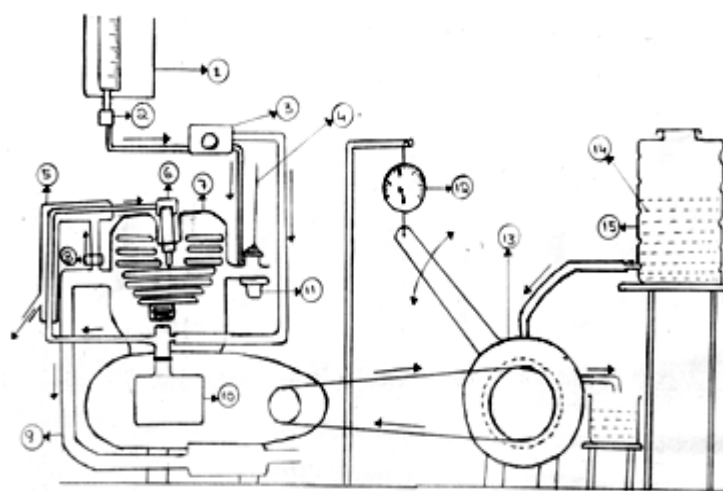

Fig 2: 1. Fuel tank s   2. Control valve   3. Three way valve
4. Carburetor   5. Injector 6.Engine 7.Silencer   8.Spring balance 9. Dynamometer
10. Fuel pump   11. Water   12. Water tank

7.1 Experimental Procedure:

Initially the engine is tested using conventional carburetor. The procedure is disconnecting the carburetor and connecting the fuel injection system to the engine repeat the same procedure. The engine is started and run for few minutes to reach a steady state condition. The engine once it reaches a steady state condition the engine rpm is set and the time taken for consuming a known volume of fuel is measured. This measurement is done under two conditions at constant speed of the engine, at no load, under the load. The power developed by the engine is measured.

Basic Measurements: Engines are power producing systems. In order to determine their capacities and suitability for applications, it is necessary to measure their levels of performance in meeting various requirements. The important parameters considered for the measurement of performance of the engine are:

Measurement of Speed: An electrical tachometer or a digital tachometer can be used to measure the speed of the shaft.

Measurement of Fuel consumption: In this the time taken for a known volume of fuel consumption is measured and the fuel consumption rate can be calculated. The fuel consumption rate can be calculated as, Fuel consumption kg/hr=Xcc*specific gravity of fuel/1000*t

Measurement of Brake Power: It involves the determination of torque and power developed at the engine output shaft. The torque is measured by the hydraulic dynamometer. The hydraulic dynamometer is run by the chain sprocket arrangement provided between the engine output shaft and dynamometer's sprocket. Brake power=2πNT/60000kw

Specific Fuel Consumption: It is the amount of fuel consumed per unit of power developed per hour. It is a clear indication of the efficiency with which the engine develops power from the fuel.SFC= (fuel consumed in kg/kW.hr)/(power developed). **Brake Thermal Efficiency:** Brake thermal efficiency=brake power/(heat supplied/sec)The readings and results obtained are listed in the table 1 and respective graph are plotted shown in fig.3.Measurement of HC and CO instruments are shown in Fig.3

Table 1

a. **By Using Injector**

Sl.no	Load (N)	Speed (rpm)	Fuel Consumption(cc)	Time (sec)	Bp (kw)	Sfc Kg/kw-hr	Tfc (kg/hr)	ή bth
1	0	1330	50	153	-	-	0.88	-
2	19.62	1330	50	146	1.912	0.48	0.921	16
3	39.24	1330	50	136	3.825	0.25	0.9926	31.5
4	58.86	1330	50	131	5.738	0.17	1.03	45.6
5	78.48	1330	50	130	7.651	0.13	1.038	60.3

CO= 2.92%vol   HC=292ppm

b. **By Using Carburetor**

Sl.no	Load (N)	Speed (rpm)	Fuel Consumption (cc)	Time (sec)	Bp (kw)	Sfc Kg/kw-hr	Tfc (kg/hr)	ή bth
	0	1330	50	80	-	-	1.6875	-
2	19.62	1330	50	71	1.912	0.99	1.901	8.23
3	39.24	1330	50	63	3.825	0.56	2.142	14.61
4	58.86	1330	50	58	5.738	0.40	2.327	20.1
5	78.48	1330	50	51	7.651	0.34	2.64	23.71

CO= 3.68%vol   HC=366ppm

c. **By Preheating The Carburetor**

Sl.no	Load (N)	Speed (rpm)	Fuel Consumption (cc)	Time (sec)	Bp (kw)	Sfc Kg/kw-hr	Tfc (kg/hr)	ή bth
1	0	1330	50	144	-	-	0.9375	-
2	19.62	1330	50	132	1.912	0.534	1.0227	15.37
3	39.24	1330	50	121	3.825	0.29	1.115	28
4	58.86	1330	50	100	5.738	0.235	1.35	34.7
5	78.48	1330	50	80	7.651	0.217	1.68	37.26

CO= 3.16%vol   HC= 308ppm

d. By Preheating The Fuel Injection Line

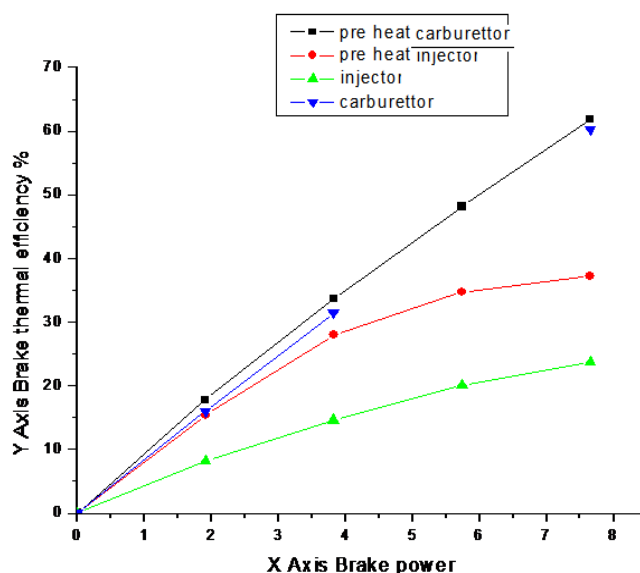| Sl.no	Load (N)	Speed (rpm)	Fuel Consumption(cc)	Time (sec)	Bp (kw)	Sfc Kg/kw-hr	Tfc (kg/hr)	ή bth
1	0	1330	50	160	-	-	0.84	-
2	19.62	1330	50	152	1.912	0.461	0.88	17.78
3	39.24	1330	50	144	3.825	0.243	0.93	33.67
4	58.86	1330	50	138	5.738	0.170	0.978	48.01
5	78.48	1330	50	134	7.651	0.131	1.007	61.05

CO= 2.33%vol   HC=220ppm
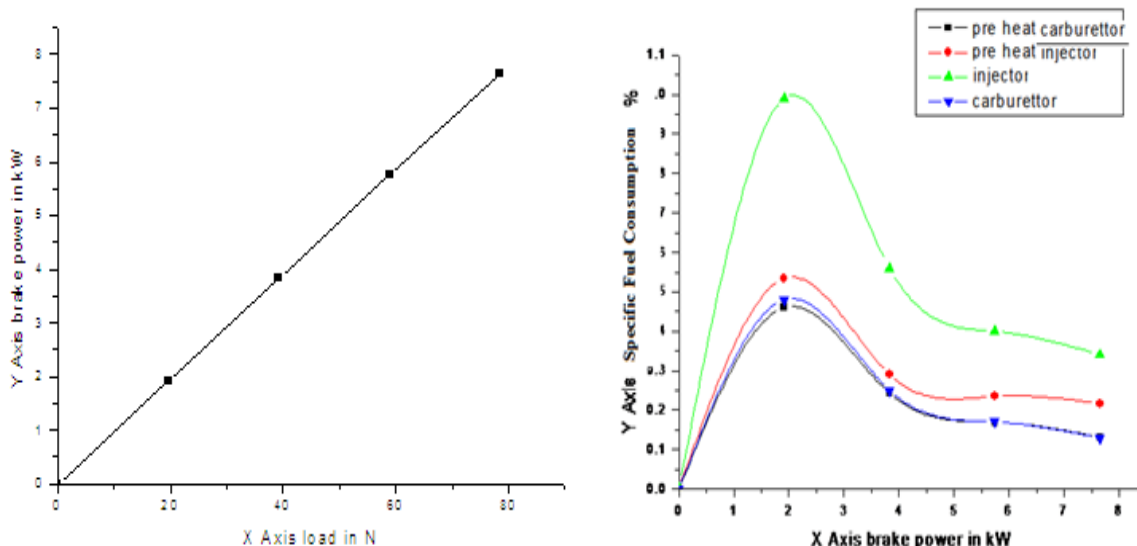
Fig: 3: a.Brake power vs Load

b.Specific fuel consumption vs brake power

c. Brake thermal efficiency vsbrake power

RESULTS AND DISCUSSION

In this work fuel injection system for 4 strokes 350cc is engine has been developed. This engine was working with poor performance. It is obvious that in carburetor engine the emission of hydrocarbons and carbon monoxide are more. This fact may be true because the engine works on quantity governing. However in order to lower the emission engine was made to run on quality governing, but the previously designed failed to give better performance now changes in injection pressure, nozzle , pumping unit and re heating of fuel affected the

performance. Therefore in this an attempt has been made to improve the gasoline direct injection system for a 350cc SI Engine. Fig 3 shows the plot for power produced with the load applied. The curve shows a linear event. The maximum power obtained is 7.65kW at 1330 rpm. The engine produces 13kW at 5600rpm, the rated power obtained when new. since the engine is old with reconditioning the engine the maximum power obtained that could be limited to 7.65 kW. The engine is working at 1330rpm, but the cursing speed of this engine is 3500rpm. At or beyond this speed gives rise to vibrations. Hence the experiment is restricted within 1330 rpm.The power produced using the fuel injection mode is almost matching with that of carburetor. The determination of full load performance helps it to compare the advantage of using fuel injection with pre heat mode. The SFC and brake thermal efficiency plotted in fig.3 have shown the variation. However, the fuel injection with pre heat mode is showing improved performance. On the whole, the results obtained have shown that fuel injection with pre heat mode can be used for existing carburetor engine. Better performance can be obtained when testing the concept with some electronic sensors and avoiding losses of leakage. In addition to this emission test have to be conducted to determine the levels of emission. This work has a great potential for further investigation.

Specimen calculation: [For load 19.62N]

Total fuel consumption: TFC $=(v*w*3600)/(1000*t)$ Where t = time taken for 50cc of fuel consumption

V=volume of fuel consumedW=specific gravity of petrol=0.75kg/m³

T.F.C=(50*0.75*3600)/(1000*152)=0.88kg/hr

Brake

powerB.P=.$(2\pi NT)/60000$Where,N=speedT=torqueW=weightR=radiusof

dynamometerB.P.=(2*π*1330*19.62*0.70)/60000=1.912kw

Specific fuel consumption: SFC=fuel consumed (kg/hr)/brake power in W=0.88/1.912=0.46kg.kW/hr

Heatsupplied: H=fuelconsumption*calorific value/3600=0.88*44000/3600=10.75 kW Where calorific value of petrol=44000kj/kg k

Brake thermal efficiency:= (brake power*100)/heatsupplied(1.912*100)/10.75=17.78%

CONCLUSIONS

The concept of preheating to the fuel injection system for a SI engine has been implemented successfully to a 3500 cc 4 stroke SI engine. After the experimental set up the engine was tested under al the following conditions Carburetor, Fuel injection (initial condition), Fuel injection (improved condition), Fuel injection with pre heat mode. The test have been conducted under no load and at different loads maintaining the speed of the hydraulic dynamometer at a constant value of 240rpm throughout the test and the engine produced a maximum power of 7.65kW, at an engine speed of 1330 rpm. Since the engine is old, the power output is very low as compared to its rated power of 13 kW at 5600rpm.Testing this engine for higher speed has resulted in uncontrollable vibrations. Therefore loading has been done to generate a maximum power of 7.65 kW and speed being 1330rpm.The comparative test result has obtained from figures indicate a slight improvement in performance when engine is working with fuel injection with pre heat mode.

8.1 Scope and Objective of Present Work:

In the present work, modifications were made for the developed direct fuel injection system. The performance of the 350 cc Bullet engine under all modification is compared with an objective to achieve better power and emission characteristics with the latter. The complete atomization of fuel is necessary to achieve proper mixing that is the mixture can be homogenous. To achieve this the atomization of fuel is done by using preheating the fuel before it is ignited by the nozzle thus the fuel preheated atomizes well compared   to cooler fuel. The present work gives way for improvement of performance of the engine.
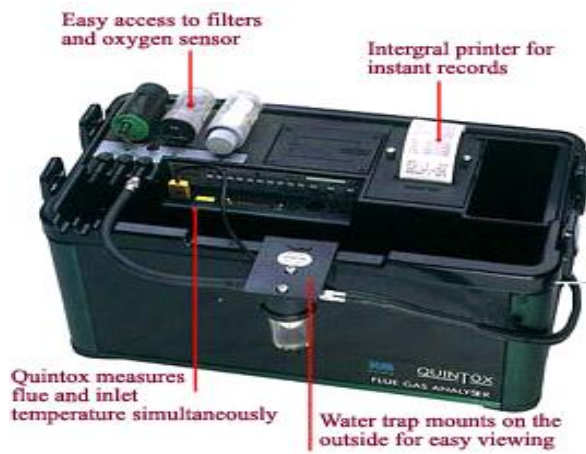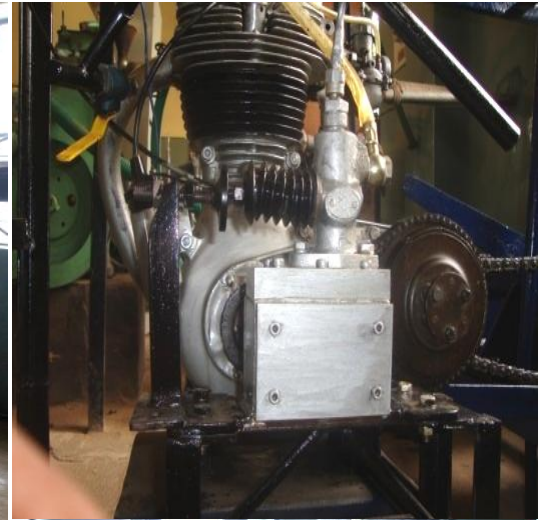
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EXPERIMENTAL SETUP PHOTOS

Easy access to filters
and oxygen sensor

Intergral printer for
instant records

Quintox measures
flue and inlet
temperature simultaneously

Water trap mounts on the
outside for easy viewing

The photo shows Experiment conducted in a laboratory