USAGE OF ETHANOL BLENDED PETROL: EXPERIMENTAL INVESTIGATIONS OF REDUCTION IN POLLUTION LEVELS IN SI ENGINE

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ABSTRACT

An experimental study was conducted to evaluate what extent ethanol blends in Petrol helps in reduction of pollution levels of SI engines exhaust emissions. Ethanol blends E5, E10, E15, E20, E22 were tested and found considerable reductions in the pollutant levels of CO, CO2, HC. The results indicate better combustions in petrol engine with ethanol blends. The reductions in HC and CO were to the extent of 80% to 90% compared to pure petrol fuelled IC engine.

KEYWORDS— *Ethanol blended bio-fuels, Air pollution, SI Engine*

I. INTRODUCTION

A challenge that humanity must take seriously[5] is to limit and decrease the greenhouse effect caused by various human activities. A major contributor to the greenhouse effect is the transport sector due to the heavy, and increasing, traffic levels. In spite of ongoing activity to promote efficiency, the sector is still generating significant increases in CO_2 emissions. As transport levels are expected to rise substantially, especially in developing countries, fairly drastic political decisions may have to be taken to address this problem in the future. Furthermore, the dwindling supply of petroleum fuels will sooner or later become a limiting factor. Earlier studies indicate[3] an important step in efforts to solve the problem is to replace fossil source energy with bioenergy. In the transport sector this means either introducing bio fuels and using adapted vehicles, or blending bio fuels with petroleum-based fuels for use with present vehicle fleets. The two alternatives are not, of course, mutually exclusive. However, blending bio fuels with petroleum-based fuels for use by the present conventional vehicle fleets has the advantages that even using quite low blending concentrations will result in substantial total volumes of gasoline being substituted by bio fuels, and that the present infrastructure for distributing fuels can be used. Today, the transport sector is a major contributor to net emissions of greenhouse gases, of which carbon dioxide is particularly important. In Sweden this sector accounts for roughly 20% of total energy consumption, and almost 50% of the total net emissions of carbon dioxide. The carbon dioxide emissions originate mainly from the use of fossil fuels, mostly gasoline and diesel oil in road transportation systems, although some originates from other types of fossil fuels such as natural gas and Liquefied Petroleum Gas (LPG). If international and national goals (such as those set out in the Kyoto protocol) for reducing net emissions of carbon dioxide are to be met, the use of fossil fuels in the transport sector has to be substantially reduced. This can be done, to some extent, by increasing the energy efficiency of engines and vehicles and thus reducing fuel consumption on a volume per unit distance travelled basis. Since, the total transportation work load is steadily increasing such measures will not be sufficient if we really want to reduce the emissions of carbon dioxide. In order to reduce absolute amounts of these emissions we have to go further and an additional measure that will be required is to replace fossil vehicle fuels with renewable ones. Primarily, especially in the short term, this means bio-based fuels. Probably the best candidate bio fuel to replace gasoline in the short term are alcohols. Alcohols can be blended with gasoline or used as neat fuel in both spark ignition engines and compression ignition engines. In the medium term, ethanol produced from grain will probably be the most important alternative fuel for replacing gasoline, and in the long term ethanol produced from cellulose might take over from grain ethanol. The advantages of ethanol are that it can

- provide a viable alternative to reduce the greenhouse effect
- be produced domestically, thereby reducing dependence on imported petroleum
- be easily mixed with gasoline
- be used (and already is on a wide scale) as an oxygenate in gasoline
- create new jobs in the country related to its production

The idea of adding low contents of ethanol or methanol to gasoline is not new, extending back at least to the 1970s, when oil supplies were reduced and a search for alternative energy carriers began in order to replace gasoline and diesel fuel. Initially, methanol was considered the most attractive alcohol to be added to gasoline. Since methanol can be produced from natural gas at no great cost, and is quite easy to blend with gasoline, this alcohol was seen as an attractive additive. However, when using methanol in practice it became clear that precautions had to be taken when handling it and that methanol is aggressive to some materials, such as plastic components and even metals in the fuel system. A lesson learned was that new, more resistant materials had to be used in the fuel system of the vehicles as well as in the distribution system. These experiences were also of great value when ethanol came to be more commonly used as an alternative to the commercial fuels, since even ethanol can be characterized as an aggressive fluid, albeit somewhat less so than methanol. The interest in producing an alternative fuel based on biomass has also been a major factor in the early choice between methanol and ethanol. The use of E85, a mixture of 85% ethanol and 15% gasoline, for FFVs has become common. Blends with other percentages of ethanol in gasoline are commonly used in various countries around the world, especially Australia (officially 10%), Brazil (up to 25%), Canada (10%), Sweden (5%) and the USA (up to 10%). There is still debate about whether, how and to what extent ethanol in gasoline may affect the materials in the vehicle and cause excessive wear of parts in the fuel system and the engine.

Ethanol fuel is ethyl alcohol, the same type of alcohol is found in alcoholic beverages. Its octane value is high and can be blended with petrol because of its density; which is similar to petrol. This blend is used as fuel in spark ignition engines. The resultant exhaust gas emissions are found to have much lower contents of CO, CO_2, HC, NOX. Ethanol is produced mainly from Molasses, which is a bye-product of sugar industries and is flammable. Interestingly, both alcohols and gasoline don't burn in their liquid forms. The answer has to do with oxygen (molecular oxygen). Combustion requires oxygen and only gasoline or alcohol exposed to oxygen can burn. In the liquid form, both substances are packed tight enough to prevent too much oxygen from entering the liquid. This is why gasoline burns better when sprayed into an engine by a fuel injector. It is also the reason why the surface of ethanol burns and not the entire liquid content. So, both fuels need to be aerosolized in order to burn efficiently.

When combustion of ethanol occurs, the combustion equation is

$$C_2 + H_5 + OH \longrightarrow 2CO_2 + 3H_2O + \triangle \quad (1)$$

Ethanol is most commonly used to power automobiles, though it may be used to power other vehicles, such as farm tractors, boats and airplanes. Ethanol (E100) consumption in an engine is approximately 51% higher than for gasoline since the energy per unit volume of ethanol is 34% lower than for gasoline. The higher compression ratios in an ethanol-only engine allow for increased power output and better fuel economy than could be obtained with lower compression ratios. In general, ethanol-only engines are tuned to give slightly better power and torque output than gasoline-powered engines. In flexible fuel vehicles, the lower compression ratio requires tunings that give the same output when for maximum use of ethanol's benefits, a much higher compression ratio should be used. Current high compression ethanol engine designs are approximately 20 to 30% more fuel efficient than their gasoline-only counterparts. Ethanol causes damage to fuel systems and engines that pure

gasoline does not. Ethanol is alcohol, and alcohol causes corrosion in the fuel system. Metal parts rust and plastic parts become deformed or cracked.
Ethanol is a quasi-renewable energy source[4] because while the energy is partially generated by using a resource, sunlight, which cannot be depleted, the harvesting process requires vast amounts of energy that typically comes from non-renewable sources. Creation of ethanol starts with photosynthesis causing a feedstock, such as sugar cane or a grain such as maize (corn), to grow. These feed stocks are processed into ethanol. Bio-ethanol is usually obtained from the conversion of carbon-based feedstock. Agricultural feed stocks are considered renewable because they get energy from the sun using photosynthesis, provided that all minerals required for growth (such as nitrogen and phosphorus) are returned to the land. Ethanol can be produced from a variety of feed stocks such as sugarcane, bagasse, miscanthus, sugarbeet, sorghum, grain, switchgrass, barley, hemp, kenaf, potatoes, sweetpotatoes, cassava, sunflower, fruit, molasses, corn, stover, grain, wheat, straw, cotton, other biomass, as well as many types of cellulose waste and harvesting, whichever has the best well-to-wheel assessment. The basic steps for large-scale production of ethanol are: microbial (yeast) fermentation of sugars, distillation, dehydration (requirements vary, see Ethanol fuel mixtures, below), and denaturing (optional). Prior to fermentation, some crops require saccharification or hydrolysis of carbohydrates such as cellulose and starch into sugars. Saccharification of cellulose is called cellulolysis. Enzymes are used to convert starch into sugar.

A. Aim of Study

The objectives of our work are the following based on earlier studies[6]:

- The aim of the project is evaluation of performance and emission characteristics of Ethanol blended Petrol.
- Presently 5% Ethanol blended Petrol is mandatory in India but it is not implemented, 5% EBP can replace around 1.8 million barrel of crude oil. Our work will throw light on the issue.
- Ethanol production creates domestic job which will help improve the per capita income.
- Present state is not very encouraging, Brazil is already using E25 so the project is an effort towards achieving better air pollution.
- The ethanol blends varied from E5, E10, E15, E20, E22 and pure petrol.
- Compression ratios[6] were 10.3 and 11.03 Brake Horse Powers and contents of CO, CO_2, HC, O_2 in exhaust gases were measured at no load condition.
- This experimental study aims to determine the variations in pollution levels of CO, CO_2, HC, O_2 of a four stroke petrol engine with varying amounts of ethanol blending and at two different compression ratios.

B. Organization of the Paper

The next section describes the preparation of blends and the equipments used in the experimental analysis. Section III shows sample calculations of brake power and presents the observations of the experiments. The exhaust gas analysis is described in Section IV. Section V gives concluding remarks, while Section VI presents future directions.

II. EXPERIMENTAL STUDY

For evaluation of exhaust and performance characteristics ethanol blends E5, E10, E15, E20, E22 are prepared in bio technology department laboratory. 200 ml of each blend was prepared. Ethanol (ethyl alcohol, C_2H_6O) was processed and supplied from Vasu Scientific Co. Ltd. The refined ethanol alcohol was found to be colourless having concentration of 99.7%extracted from sugar molasses. Petrol fuel was used as a reference fuel in this study. The petrol fuel is a volatile, flammable liquid obtained from local fuel petroleum stations.
Blends were prepared simply by pouring petrol and ethanol constituents into a container and mixing them. Up to 20% ratios in 5% increments and a 22% ratio by volume of the two constituents were prepared for fuels test samples. These micro-emulsions were found to be stable and homogeneous as no distinct phase separation was observed. For testing homogeneity, the blends were mixed thoroughly in a mechanical shaker with no signs of separation. An easy way to comply with the

conference paper formatting requirements is to use this document as a template and simply type your text into it.

Five 250 ml conical flasks were first thoroughly cleaned by acetone then 10 ml , 20 ml , 30 ml , 40ml and 44ml ethanol was poured into five flasks and each flask was filled up to 200 ml by pouring petrol. After blending the samples are mixed thoroughly on mechanical shaker for 24 hours to ensure no separation of ethanol and petrol. A mechanical shaker is a piece of laboratory equipment used to mix, blend, or to agitate substances in tube(s) or flask(s) by shaking them, which is mainly used in the fields of chemistry and biology. A shaker contains an oscillating board which is used to place the flasks, beakers, test tubes, etc. The mechanical shaker (as shown in Fig.2) used was MS 400 of LAB TOP INSTRUMENTS PVT. LTD. It performs repetitive shock, loose load, or bounce tests in accordance with ISTA, ASTM, TAPPI, ISO, MIL-STD, UN, DOT, and other industry, government, and international standards. The MS 400 operates on an eccentric cam principle, and can be easily adjusted to perform circular-synchronous or vertical linear motions. The MS 400 can handle individual packages and/or containers weighing up to 400 lbs. (181 kg). The standard test platform is 48 in. (122 cm) square. The operating frequency range is from 2 – 5 Hz., with a fixed 1 in. (2.54 cm) displacement and a maximum acceleration of 1.25g peak. The blends are as shown in Fig. 1.

Figure 1: Ethanol Blends

Figure 2: Mechanical shaker

A. Equipments Used

The equipments used in our project are listed below with a brief description followed by its specification. Fig. 1 shows complete project setup. Following equipments were used in the study (see Fig. 2) :

1. IC Engine: Standard Pulsar-150 model bought, refurbished and some modifications done. It is a DTSi Engine with twin spark plug.
2. Prony Brake Dynamameter: The Prony Brake[8] is a simple device invented by Gaspard de Prony to measure the torque produced by an engine. It generally includes a rotating brake drum or disc connected with the output shaft of a prime mover, such as an internal combustion engine, and stationary friction pads or brake shoes that are engage with the drum or disc to apply a retarding force. The dynamometer we used in our experiments has 50 kg capacity with Nylon rope to apply load on the Break Drum.
3. Tachometer: It measures the speed of rotating shaft at different blend petrol of E5, E10, E15, E20 and E22. The tachometer used was DT-2236 of P.C.E INSTRUMENTS for the measurement of speed of rotation of the shaft in revolutions per minute (r.p.m).
4. Emission Testing Apparatus: Hired from an approved vendor to measure contents in exhaust gas.

Figure 3: Complete Project Equipment Setup

Figure 4a: IC Engine

Figure 4b: Prony brake dynamometer

Figure 4c: Spring Balance

Figure 4d: Brake drum

Figure 4e: Tachometer

B. Modifications to IC Engine

1. Cylinder Bore Diameter: By increasing bore of cylinder, swept volume of cylinder piston is increased which increases compression ratio

2. Piston change: A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall. After reboring the piston is replaced by bigger piston having diameter 0.5 mm greater than the previous piston to match the bored cylinder.

3. Cam Shaft: Cam shaft is replaced by new one for attaining suitable timing of fuel inlet and exhaust. As the inlet and exhaust valve are changed accordingly attain the new compression ratio, so the old cam shaft is replaced by a new one. In internal combustion engines with pistons, the camshaft is used to operate poppet valves. It then consists of a cylindrical rod running the length of the cylinder bank with a number of oblong lobes protruding from it, one for each valve. The cam lobes force the valves open by pressing on the valve, or on some intermediate mechanism as they rotate.

4. Inlet and Exhaust Valves: Valves are replaced with the 1.3 times larger diameter valves to fit with the new bored head. The valve sizes were increased to increase the fuel supply into the engine cylinder.

5. Cylinder Head: Facing is done on head of engine to reduce its clearance volume and to increase its compression ratio.

6. Rocker Arm And Timing Chain: A rocker arm is an oscillating lever that conveys radial movement from the cam lobe into linear movement at the poppet valve to open it. One end is raised and lowered by a rotating lobe of the camshaft. Rocker arm is changed with a new one to match with new cam shaft. A timing belt, timing chain or cam belt is a part of an internal combustion engine that synchronizes the rotation of the crankshaft and the cam shaft so that the engine's valves open and close at the proper times during each cylinder's intake and exhaust strokes. The timing chain is changed to a new one as the old chain had lost its strength.

The flow of blended petrol was by a pipe in which a graduated pipette was connected and made to flow into the carburetor so as to measure flow rate of fuel. The C.R was increased from 10.3 to 11.03 by reboring the cylinder from 63.1 mm Dia. to 63.6 mm. The pollution levels were checked at both these C.R.'s for all blends of ethanol viz E5, E10, E15, E20 and E22. The contents of CO, CO_2, HC, O_2 in exhaust gas was checked at a commercial emission testing centre which is approved by state (Karnataka) RTO authority. The blending of Ethanol with petrol was done in Biotechnology Lab. The measured quantities of petrol 200ml and ethanol of 10, 20, 30, 40, 40, 44 were taken and mixed in a 250ml flask. The mixed liquids were placed on a mechanical shaker for 24 hours for a homogeneous mixing.

III. PERFORMANCE EVALUATION

Performance test i.e., test to find out brake power is conducted with ethanol blended petrol as fuel. Different blends i.e. E5, E10, E15, E20, E22 are used in engine as fuel and brake power is measured for each blend. To increase compression ratio from 10.39:1 to 11.03:1 for making engine suitable for higher blends cylinder is bored. To find out brake power of engine Prony brake dynamometer is used. Test is conducted at a constant load and constant fuel supply for both the Compression ratios. Using a tachometer speed of crank shaft is measured for each blend and then brake power is calculated

$$b_p = \frac{2\pi N\tau}{60} \qquad (2)$$

where tau is the torque in Newton meter (Nm), N is the rotational speed in rotations per minute and b_p is the brake power in watt.

A. Calculation of the brake power[8]

Constants: Load= 3 kg, Torque = load x Brake drum radius= 3x9.81x0.07 = 2.0601 Nm,

$$B_p = \frac{2 \times 3.142 \times 57.7 \times 2.0601}{60000} = 0.0124\text{kW} \quad (3)$$

Variables: For petrol the calculation is as shown below:

Fuel	Speed
Petrol	57.7
E5	53.5
E10	49.4
E15	44.7
E20	41.2
E22	38.3

Table 1: Speed of Crank Shaft for different blends

The brake power was calculated in a similar fashion for other blends as well.

B. Test Observations

All test observations and data are listed in the tables 2 and 3.

Load (KG)	Fuels	Speed (RPM)	Torque (Nm)	Power (KW)	Fuel Consumption 50ml (in Sec)	Specific Fuel Consumption (Kg/KWhr)
3	Petrol	57.7	2.0601	0.0124	185.02	60.46
3	E5	53.5	2.0601	0.01154	179.76	64.15
3	E10	49.4	2.0601	0.01065	171.64	72.9
3	E15	44.7	2.0601	0.0096	158.08	88.25
3	E20	41.2	2.0601	0.0089	150.83	100.092
3	E22	38.3	2.0601	0.0083	145.17	111.65

Table 2: Performance Test: C.R 10.39 : 1

Load (KG)	Fuels	Speed (RPM)	Torque (Nm)	Power (KW)	Fuel Consumption 50ml (in Sec)	Specific Fuel Consumption (Kg/KWhr)
3	Petrol	59.2	2.0601	0.0128	176.26	58.93
3	E5	55.4	2.0601	0.012	170.71	64.9
3	E10	53.4	2.0601	0.0115	163.18	71.14
3	E15	53.1	2.0601	0.0116	150.74	76.56
3	E20	50.2	2.0601	0.0108	142.25	87.46
3	E22	47.2	2.0601	0.0102	136.82	96.587

Table 3: Performance Test: C.R 11.03 : 1

IV. EXHAUST GAS ANALYSIS

The test was carried out with the engine mounted on a test bench and connected to a dynamometer. The gaseous emissions from the exhaust of the engine include hydrocarbons, carbon monoxide and oxides of nitrogen. During a prescribed sequence of warmed up engine operating conditions the amounts of the above gases in the exhaust were examined continuously on no load condition. The exhaust gas emissions were measured by an approved (by Regional Transport Office (RTO), Karnataka) emission testing centre in Bangalore near the institute.

A. Calculation of the brake power

Exhaust emissions refer to gases emitted from the cylinder after combustion and power is developed. The composition of emissions depends on the composition of the exhaust streams leaving the engine after combustion and on the effectiveness of any pollutant-reducing measures employed in the exhaust system downstream of the engine. Most of the pollutant components of exhaust emissions originate in the process of fuel combustion in the engine. Perfect combustion of any sample of fuel would involve complete oxidation of the entire sample with maximum heat production and no pollutant emissions. This would require complete mixing of exactly reacting quantities of the pure fuel and oxygen with the addition of an appropriate amount of heat. For hydrocarbon fuels, the only products of combustion would be carbon dioxide, water vapour and heat. The combustion of fuels in practical internal combustion engines is not perfect for a number of reasons:

- The fuel is burned in air, which contains other elements in addition to oxygen; in particular, nitrogen present in the air (78\% by volume) can react with oxygen to produce NOx Note that carbon dioxide was traditionally not viewed as a pollutant. However, with more recent recognition of the role of human-induced emissions of greenhouse gases such as carbon dioxide in promoting global climate change, emissions of carbon dioxide which do not form part of a closed cycle cannot be considered to be nonpolluting.
- The control of fuel ignition or injection timing may not always achieve combustion at optimal conditions As a result, exhaust gases leaving the engines of motor vehicles always contain some pollutant compounds.

The conditions and processes that lead to formation of the major pollutants are summarized below.

B. Carbon Monoxide

Carbon monoxide emissions are caused by incomplete combustion of fuels. This most often occurs when the ratio of air to fuel in the combustion chamber is too low for complete combustion, or when there is inadequate mixing of fuel and air, leading to isolated pockets where the air-fuel ratio is too low for complete combustion. When the air-fuel ratio is too low, there is insufficient oxygen to convert all the carbon in the fuel to carbon dioxide. A small amount of carbon monoxide is also formed when there is much more air than required for complete combustion (i.e., very weak fuel-air mixtures), due to chemical kinetic effects.

C. Hydrocarbons

Hydrocarbons emitted with engine exhaust gases are composed of unburned fuel and products of partial combustion (such as ethylene) that were still present (i.e., not yet combusted) in engine cylinders at the beginnings of the engine exhaust strokes. This failure to complete combustion during the power stroke is generally related to the movement of fuel mixtures and speed of propagation of the flame in the engine cylinders during the power stroke. Abnormal engine operation, such as cylinder misfiring, can also cause significant quantities of hydrocarbons to be introduced into the engine exhaust stream.

D. Carbon Dioxide

Carbon dioxide is a greenhouse gas. Motor vehicle CO2 emissions are part of the anthropogenic contribution to the growth of CO2 concentrations in the atmosphere which is causing climate change. Motor vehicles are calculated to generate about 20% of the European Union's man-made CO2 emissions, with passenger cars contributing about 12\%. European emission standards limit the

CO_2 emissions of new passenger cars and light vehicles. The European Union average new car CO_2 emissions figure dropped by 5.4% in the year to the first quarter of 2010, down to 145.6 g/km.]

E. Oxygen

The O_2 sensor is mounted in the exhaust manifold to monitor how much unburned oxygen is in the exhaust as the exhaust exits the engine. Monitoring oxygen levels in the exhaust is a way of gauging the fuel mixture. It tells the computer if the fuel mixture is burning rich (less oxygen) or lean (more oxygen).

V. CONCLUSIONS

- The conclusions are in agreement with earlier studies (ref.6)
- The study establishes reductions in CO,CO_2,HC for all ethanol blends and found highest reductions for E15 blend.
- The power reductions are 9.167% for E15 blend but reduction in CO is 92.97% and HC reductions are 89.7%
- It is clear from this study that the combustions are more complete and efficient for all ethanol blends compared to pure petrol.
- Though power generated and specific fuel consumption are lower with higher blends , the reductions in pollution levels are much higher and are good for greener environment.

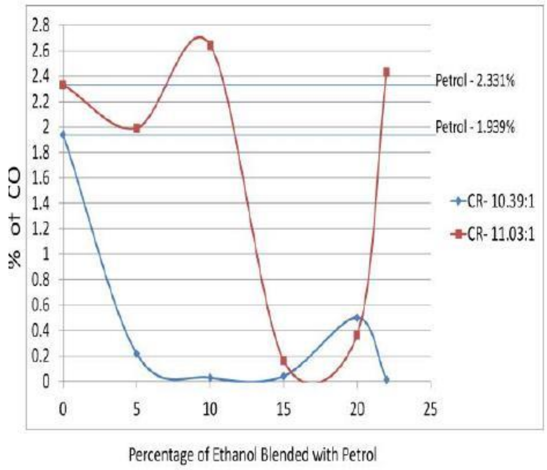

Figure 5: % of CO

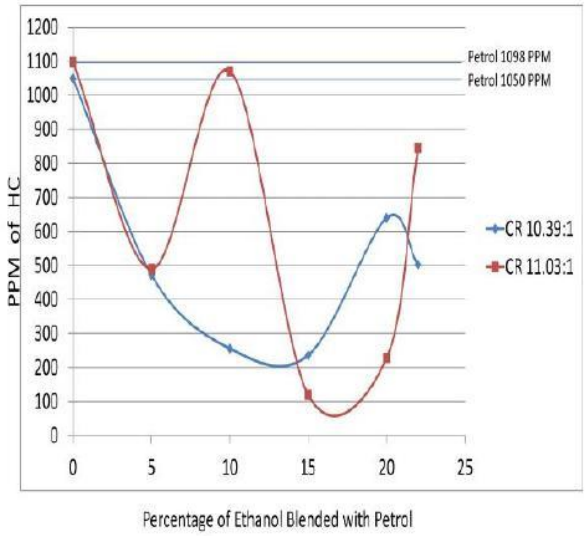

Figure 6: PPM of HC

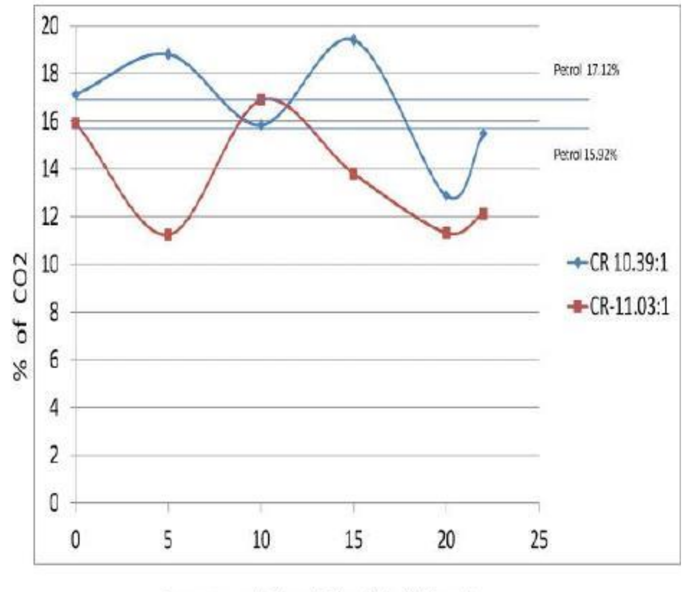

Figure 7: % of CO2

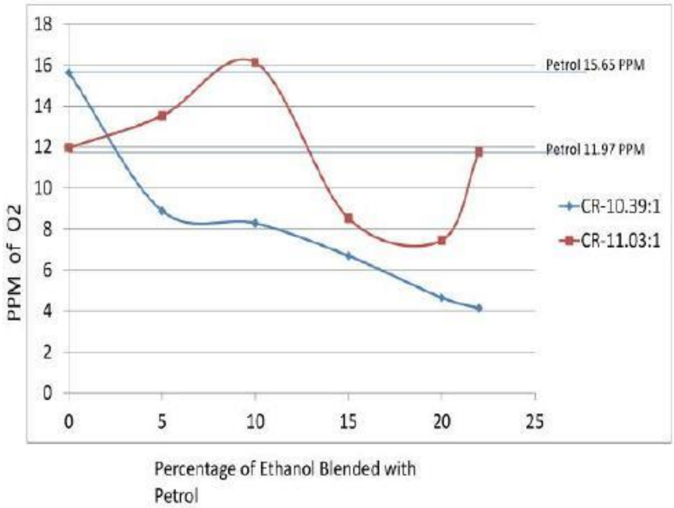

Figure 8: PPM of O2

VI. FUTURE WORK

The performance and exhaust gas tests can be carried out with blends E25, E30, E50, E60, E80, E90 and E100. We also need to determine the optimum blends w.r.t pollution levels. The effects of Ethanol on various parts of IC engine w.r.t corrosion characteristics specially on seals, gaskets etc. Study of combustion characteristics, measurement of IHP and determination of Mechanical efficiency, thermal efficiency, Specific Fuel Consumption, Brake Thermal efficiency and Indicated Thermal efficiencies.

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