EXHAUST EMISSION ANALYSIS OF AN INTERNAL COMBUSTION ENGINE FUELLED WITH HYDROGEN-ETHANOL DUAL FUEL

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Abstract The work presented in this paper is an attempt to evaluate the exhaust emission characteristics of a hydrogen-ethanol dual fuel combination with different percents of hydrogen substitutions (i.e. 0-80 % by volume and of 20 % increment) at three different compression ratios of 7:1, 9:1 and 11:1. Experimental investigations have been carried out on a computer interfaced with; four-stroke cycle, single-cylinder, compression ignition (CI) engine, which was converted to spark ignition (SI) and carburetion, to suit ethanol fuel and a provision was made at the inlet manifold of the said engine to induct hydrogen gas. The effect of hydrogen substitutions on CO, HC, NO_x emissions at 7, 9 and 11 compression ratios were determined. It was found that, at 100 % load, the percentage of hydrogen substitution varied from zero to 80 % and the NO_X emissions increased by 58.62, 59.3, 62.74 % for 7, 9, 11 compression ratios respectively. When the effect of compression ratio changed from 7:1 to 11:1 the same change took place in the percentage of substitution which was a reduction of CO and HC by 30.4 and 21.67 %.

Keywords Hydrogen, Ethanol, Compression Ratio, Spark Ignition, Emissions

چکیده این مقاله سعی در ارزیابی مشخصات دود خروجی حاصل از سوخت دوگانه هیدروژن – اتانول با درصدهای مختلف جانشینی هیدروژن (یعنی ۰ تا ٪۸۰ حجمی، با نمو ٪۲۰) و در سه ضریب تراکم ۷:۱ ، ۹:۱ و ۱۱:۱ دارد. تحقیقات آزمایشگاهی بر روی یک موتور چهار زمانه تک سیلندر تراکم احتراقی (CI) که مجهز به کامپیوتر بوده و به احتراق جرقه ای (SI) تغییر یافته و عمل کربن دهی برای سازگاری با اتانول و عملیات لازم برای ورود گاز هیدروژن در ما نیفلد ورودی آن انجام شده، صورت می پذیرد. تاثیر درصد جانشینی هیدروژن بر میزان خروجی CO، HC، NO_x در نسبت تراکم های ۷، ۹ و۱۱ تعیین شده. نشان داده شده که در ٪۱۰۰ بارگذاری، هنگامی که درصد جانشینی هیدروژن از ۰ تا ٪۸۰ تغییر می کند، میزان خروج NO_x به اندازه ۵۵,۶۲، ۵۹,۳ و ٪۶۲,۷۴ به ترتیب برای نسبت تراکم های ۷، ۹ و ۱۱ افزایش می یابد؛ در حالی که تاثیر نسبت تراکم، هنگامی که از ۷:۱ تا ۱۱:۱ تغییر می کند، برای همان تغییر در درصد جانشینی کاهش CO، HC به اندازه ۳۰,۴ و ٪۲۱,۶۷ است.

1. INTRODUCTION

Among the various alternative fuels, hydrogen and alcohol are very attractive substance for the role of the energy vector in many practical applications. While conventional energy sources such as natural gas, oil and coal are non-renewable, hydrogen and alcohol can be coupled to be a renewable energy sources. Alcohol fuels have caught special attention in the past few years. For example, ethanol has many beneficial properties that improves with gasoline. Ethanol has a higher octane rating and is considered a renewable fuel and for its practicality, the engine needs only slightl modification. Government of India has already introduced a petrol blend with five percent ethanol to be used in motor vehicles in nine states [1]. Ethanol is currently being used as an additive (10 % by volume) for gasoline. A mixture of 85 % ethanol and 15 % gasoline is being used in the Midwest. However, it is feasible that sometime in the future, ethanol could be used as a complete replacement for gasoline, thereby reducing India's reliance on oil [2]. There are some drawbacks in using ethanol. One of the primary problems to use ethanol is the cold start operation. Another drawback is its high cost and limited availability. However, with world petroleum prices over $100 per barrel, ethanol could be shown to be more economical [3].

Enriching ethanol with hydrogen could help to solve the cold starting issue, while adding many other advantages. Hydrogen enriching of fuels has been shown to extend the lean limit of the fuel and enable high dilution combustion regimes. The lean fuel mixture helps the reduction of carbon monoxide (CO) and hydrocarbons (HC) as well as to some extent nitrogen oxides (NO_x) due to the lower temperature.

Hydrogen is characterized by having the highest energy–mass coefficient of the chemical fuels and in terms of mass energy consumption; hydrogen exceeds the conventional alcohol fuels by about five times (Table 1). Therefore, hydrogen addition reduces the specific fuel consumption of the ethanol engine. The advantage of hydrogen-supplemented fuel is that it requires a smaller quantity of hydrogen, which considerably reduces the problems connected with hydrogen storage in automobiles [4]. The increase in compression ratio (CR) is possible with ethanol because of its high octane number [5]. Operation at high CR reduces fuel consumption, which is relatively high, because of alcohol's low heat combustion [6].

2. LITERARY SURVEY

Most researches have reported, the hydrogen-enrichment concept using a variety of gasoline and diesel fuels which has shown a significant increase in efficiency along with a great reduction in both NO_X and hydrocarbon emissions [8]. No research has focused on ethanol as the primary fuel.

The only work done at this time with an ethanol and hydrogen fuel mixture was by Baghdadi at the University of Babylon in Iraq. Al-Baghdadi, et al [4] studied the effect of hydrogen-ethanol addition on the performance and exhaust emission of a spark ignition engine. The results of his study showed that all engine performance parameters had improved when operating the gasoline spark ignition engine with dual addition of hydrogen and ethyl alcohol.

Addition of ethanol has improved, NO_x reduction, that was reported in the literature [4]". As further reported in the literature [4], the addition of 8 % hydrogen, with 30 % volume of ethyl alcohol into a gasoline engine operating at 9 compression ratio and 1500 rpm causes a 48.5 % reduction in CO emission, 31.1 % reduction in NO_x emission and 58.5 % reduction in specific fuel consumption. Moreover, the engines' thermal efficiency and output power increased by 10.1 and 4.72 %, respectively. When ethyl alcohol is increased over 30 %, it causes unstable engine operation, which can be related to the fact that the

TABLE 1. Properties of Hydrogen and Ethanol Fuels [7].

Property	Hydrogen	Ethanol
Stoichiometric Air-Fuel Ratio	34.32	9.0
Heat of Vaporization (kJ/kg)	–	842
Heat of Combustion (MJ/kg)	120	26.86

fuel is not vapourized and this causes a reduction in both, the brake power and efficiency.

Al Baghdadi, et al [9] also studied the performance and pollutant emission of a four-stroke spark ignition engine using hydrogen-ethanol blends as fuel. He performed tests using 2, 4, 6, 8, 10 and 12 mass % hydrogen-ethanol blends. Gasoline fuel was used as the basis for comparison. The effect of using different blends of hydrogen-ethanol on engine power, specific fuel consumption, CO, NO_X emission was studied. Operating test results for a range of compression ratio (CR) and also equivalent ratio are presented. The results show that the supplemental hydrogen in the ethanol-air mixture improves the combustion process and hence improves the combustion efficiency, expands the range of combustibility of the ethanol fuel, increases the power, reduces the specific fuel consumption (SFC) and also reduces toxic emissions. The important improvement of hydrogen addition is reducing the SFC of ethanol engines. Results were compared to those with gasoline fuel at 7 CR.

In the present work 7, 9, 11 compression ratios, different hydrogen substitutions to ethanol in volume percentage (i.e. 0-80 % by volume, an of increment 20 %) were chosen to study in detail and also the emissions from the engine.

3. EXPERIMENTAL DETAILS

3.1. Description of the Set up The engine used in this study was a Kirloskar AV-1, single cylinder, direct injection diesel engine (Figure 1). The engine was modified to run at low compression ratios thus making it adaptable to run with spark ignition (SI) mode by replacing the diesel fuel system with carburetor which was connected to the air-intake

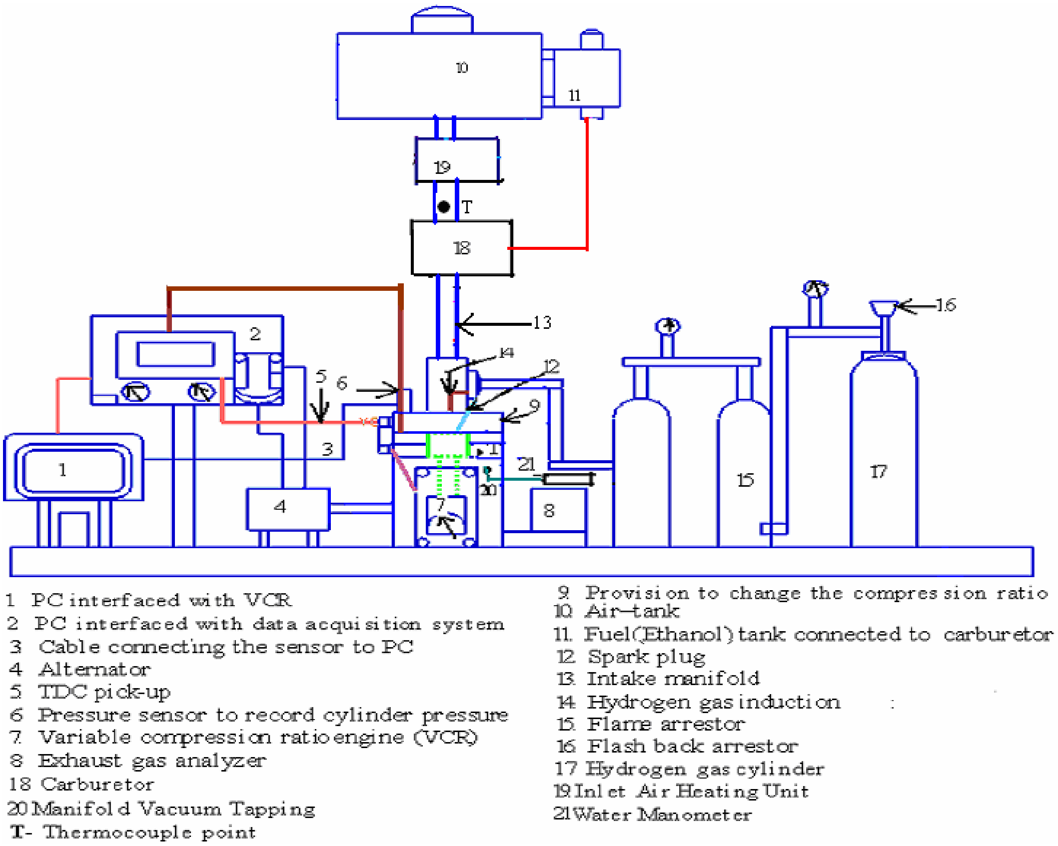

Figure 1. Experimental Test Rig with necessary instrumentation.

manifold of the engine inlet system. The diesel injector was replaced by spark plug and a provision was made to induct hydrogen gas in the inlet manifold. The engine was modified and a provision was made to vary the compression ratio from 7 to 11. The engine was coupled to a DC dynamometer and all the experiments were carried out with a constant speed of 1500 rpm. The intake temperature and pressure were chosen to operate a stable and knock free engine.

The engine emission tests were carried out to study the effect of compression ratio on hydrocarbons (HC), carbon monoxide (CO) and NO_x. These tests were conducted at three different compression ratios of 7, 9 and 11. At each compression ratio constant test runs were made for a constant speed (1500 rpm). During these performance tests, the throttle was kept wide open and the load was varied by operating the loading switches in steps of 20 (i.e. from 20-100 % load in kW). At each load set, the speed was kept constant by controlling the hydrogen and ethanol flow rate (i.e. by adjusting the hydrogen substitutions to 0-80 % with an interval of 20 %) and the spark timing corresponding to 25° was adjusted for best torque (MBT i.e. maximum advance for best torque). The engine was modified to work on low compression ratios ranging from 7:1 to 11:1 on SI mode. By adding the shims and spacer plates made of various thicknesses, the clearance volume was increased, thereby the compression ratio was reduced. Thus, the compression ratio of the existing engine that was originally 18.35, was made to vary between 7 to 11. The engine's technical details are given in Appendix 1.

3.2. Experimental Procedure

The experiments were conducted on the engine with pure ethanol (100 % by volume) and then with hydrogen substitutions in place of ethanol in 20-80 % by volume with a 20 % interval. The varied parameter was compression ratio. MBT spark timing was maintained through out these test points. After the compression ratio is set, the total setup is checked for safe operation. The hydrogen cylinder pressure was reduced before inducting the hydrogen into the inlet manifold. Safety devices like water trap and flame arrester were connected in the fuel supply line because of the hazardous nature of hydrogen. A computer interfaced piezoelectric sensor, of range 145 bar was used to note the in cylinder pressure. Engine exhausts emissions were measured using an advanced AVL five-gas analyzer, which is a non-dispersive infrared gas analyzer. The sample to be evaluated passed through a cold trap to condense the water vapors, which influences the functioning of the infrared analyzer. The exhaust gas analyzer was calibrated periodically using standard calibration gas. The hydrocarbons and NO_X were measured in terms of parts per million (ppm) as hexane equivalent and carbon monoxide emissions are measured in terms of percentage volume.

The engine was first started on liquid fuel (i.e. ethanol) and the ethanol from the fuel tank was allowed to enter the air stream through the discharge tube from there into the carburetor body and then is atomized. Because of both low calorific value and high latent heat vaporization, theoretically the engines' volumetric efficiency increased without any hydrogen substitution. However, vaporization of the intake mixture could be reduced. To avoid this problem, intake manifold was heated by providing an inlet-heating element before the carburetor. Then the ethanol is conveyed by the heated air stream, coming from the heating element, past the throttle plate and into the intake manifold. Ethanol evaporation starts within the carburetor and continues as the fuel droplets move along with the air stream. Because of this, there is a proper mixing of ethanol and air mixture and the problem of ethanol exceeding 30 % by volume and not being vapourized [4,6] is eliminated. After stable operation, hydrogen was inducted into the intake manifold at 3 to 5 bar by reducing the pressure using a pressure regulator. A hydrogen mass flow controller, which was installed in the operating pressure line, controlled the hydrogen flow automatically as the load was increased. To dampen the pressure fluctuations in the intake line, which particularly occur with large displacement single cylinder engines, a stabilizing tank is located at the inlet of the engine. The Hydrogen gas was inducted into the intake-manifold and a thermal mass flow controller controlled its flow rate. The maximum amount of Hydrogen supplied was limited by unstable operation at low outputs and by rough engine running due to knock at high out puts. When the hydrogen supply was increased, the ethanol quantity was automatically decreased by the governor mechanism of the engine to maintain the speed constant. The airflow rate was measured using a laminar flow element with an accuracy of 1 mm of water. Load, varied ranging from 20 to 100 % of full load. At each load, the amount of hydrogen also varied. The experimentation was repeated by varying the compression ratios. By varying the percentage of hydrogen substitution along with the varying load, the exhaust emissions were noted for analysis. The water supply to the engine was also maintained to avoid over heating the engine.

Prevention of explosive atmosphere on the test bench, the room was being cared for by means of monitoring any leaks from the hydrogen supply line, continuous monitoring of the test bench, air and a powerful ventilation system. The hydrogen cylinder is placed at a safe distance from the engine to avoid heat transfer to the cylinder.

4. RESULTS AND DISCUSSIONS

The amount (percentage) of hydrogen substitution in place of ethanol fuel and its effect on the engines' pollutant emission are the main issues and are discussed in detail in this paper. The experimentation was carried out for dual fuel mode, in which the percentages of hydrogen and ethanol varied according to the load requirements. The percentage of hydrogen substitution varied continuously from zero to 80 % of full load at 7, 9 and 11 compression ratios (CRs). In the present analysis, hydrogen and ethanol fractions are expressed in volume concentration.

4.1. HC Emissions Figure 2 shows the variation of hydrocarbon emission (HC) with various percentage of hydrogen substitutions at 7, 9 and 11 compression ratios at 100 % load. As shown, the HC decreases with the increasing percentage of hydrogen substitution. Even at 20 % hydrogen substitution at the mentioned CRs, since the applied load is 100 %, HC percentage is low because the combustion is complete under these conditions, due to sufficient quantity of air and higher gas temperatures in the cylinder. It was also observed that, at higher compression ratio of 11, these emissions are the lowest even at 20%

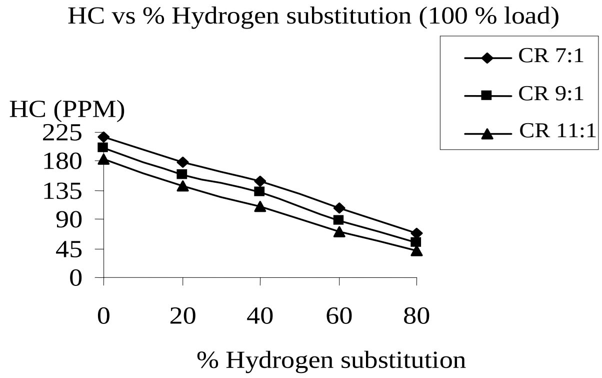

Figure 2. HC vs % hydrogen substitution.

hydrogen substitution. This is because at higher compression ratios, the compressed air temperatures are higher which promotes faster and complete combustions. With the various percentage of hydrogen substitution from zero to 80 %, the percentage reduction in the HC values are 68.2, 72.63 and 77.59 % for CR of 7, 9 and 11, respectively. The effect of compression ratio when changed from 7:1 to 11:1 for zero to 80 %, with 20 % increment, hydrogen substitutions, the HC reductions are 15.6, 20.78, 22.5, 33.64 and 40.58 %, respectively.

Thus it can be seen that, an increase in hydrogen enrichment, results in the decrease in duration of combustion and an improvement in the combustion process results in decrease in HC emission. Since the burning velocity of a hydrogen/air mixture is higher than that of the ethanol/air mixture, the burning velocity for mixtures of hydrogen and ethanol is then expected to extend over this range depending on the relative amounts of the constituents. As the burning velocity increases, the combustion duration may be shortened and the actual indicator diagram may approach the ideal diagram. A higher thermodynamic efficiency or lower brake specific fuel consumption (BSFC) which is associated with higher temperatures in the cycle is therefore expected. The observation of a lower HC emission, when an increasing amount of hydrogen is added, may suggest that a better combustion process has occurred.

4.2. CO Emissions Figure 3 shows the effect of the percentage of hydrogen substitution to ethanol on the CO emission at 7, 9 and 11 compression ratios and for 100 % load. CO concentration decreases with the increase in the percentage of hydrogen addition for all compression ratios at 100 % load. This is due to the reduction in carbon atoms concentration in the blended fuel and the high molecular diffusivity of hydrogen which improves mixing process and hence combustion efficiency.

With the increase in the percentage of hydrogen (which contain less carbon atoms in it), complete combustion and higher inside temperatures is achieved. For various percentages of hydrogen substitution, the existing amount of ethanol in it, is completely burnt, leaving only few traces of CO. As seen in Figure 3, CO is very low at higher percentages of hydrogen. As the percentage of hydrogen substitution varies from zero to 80 %, the CO emission is reduced by 72.72, 77.6 and 79.9 % for 7, 9 and 11 compression ratios respectively.

4.3. NO_x Emissions Figure 4 represents the effect of hydrogen substitution on NO_x production. Though the over all range of NO_x is low, but it is observed that as the percentage of Hydrogen increases the NO_x level also will increase. It was found to be higher, with higher compression ratios and higher percentages of hydrogen substitutions.

It is high with compression ratio of 11. The reason is that, an increase in compression ratio results in a higher level of NO_x because of increased temperature conditions. This situation also leads to high flame a speed, which as a consequence reduces the residence time. However,

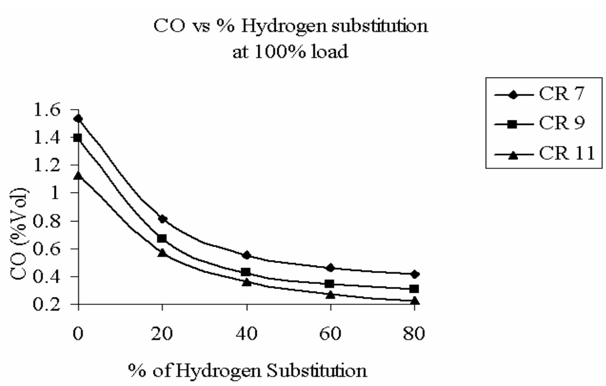

Figure 3. CO vs % hydrogen substitution.

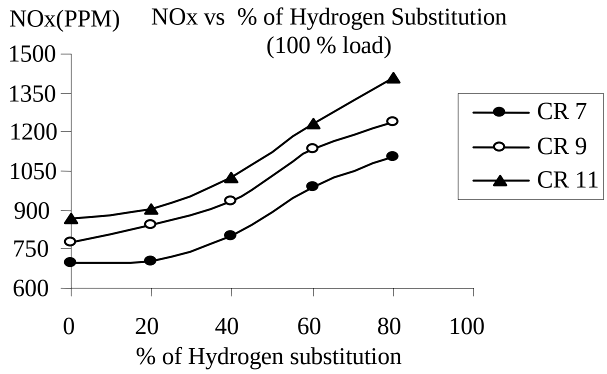

Figure 4. NO_x vs % hydrogen substitution.

it was observed that between the two factors, such as increased temperature and decreased residence time, the effects of the former predominates, thereby resulting in a high NO_x level with higher compression ratio. In addition, the operating temperatures are high, with higher percentage of hydrogen substitutions. At higher loads, increased hydrogen leads to rapid combustion and this rises NO_x level due to the rise in the flame propagation rate in hydrogen-air mixture. Thus at high loads the concentration of NO_X that can be tolerated, could be used to fix the hydrogen substitution. Therefore, from the above figure the compression ratio was seen to be influencing the level of NO_x concentration. This was in conformity with the results as reported by other researchers [10,11].

Therefore, it is observed that as the CR increases, NO_x emissions increase, for all hydrogen substitutions. With the higher CRs, the peak temperatures of the cycle will increase, whereby increased amounts of atomic oxygen are produced through dissociation. This initiates a chain reaction, resulting in higher NO_x emissions [12,13]. Since the percentage of Hydrogen substitution varied from 0 % to 80 %, it was found that the NO_X increased by 62.74 % for CR 11, at 100 % load and for CR 9, this increase was 59.3 %. For CR 7 the NO_X increased by 58.62 %. The high heating value of hydrogen is one of the reasons for operating at high temperatures. As the compression ratio increased from CR 7 to CR 11, for 80 % hydrogen substitution, the value of NO_X increased by 27.8 %, which is the effect of higher compression ratios.

5. CONCLUSIONS

The experimental investigation was carried out, to find out the exhaust emissions on a single cylinder computer interfaced, hydrogen ethanol dual fuel engine, at various compression ratios, the following observations were drawn:

- With the variation of hydrogen substitution from zero to 80 %, the percentage reduction in the HC values are 68.2, 72.63 and 77.59 % for CR of 7, 9 and 11, respectively.
- The effect of compression ratio when changed from 7:1 to 11:1 for pure ethanol and 80 % of hydrogen substitutions is a reduction of HC by 15.6 and 40.58 % respectively.
- The effect of compression ratio when changed from 7:1 to 11:1 for the same change in percentage substitution is reduction of HC by 21.67 %.
- As the percentage of hydrogen substitution varied from zero to 80 %, the CO emissions were reduced by 72.72, 77.6 and 79.9 % for 7, 9 and 11 compression ratios respectively.
- The effect of compression ratio when changed from 7:1 to 11:1 for the same change in percentage substitution is reduction of CO by 30.4 %.
- CO concentration decreased with the increase in percentage of hydrogen addition for all compression ratios at 100 % load.
- NO_x level was found to be higher, with higher compression ratios and higher percentages of hydrogen substitutions.
- At 100 % load, as the percentage of Hydrogen substitution varied from zero to 80 %, it was found that the NO_X increased by 58.62, 59.3, 62.74 % for 7, 9 and 11 compression ratios respectively.
- The important improvements of hydrogen addition to ethanol are to reduce the HC and CO emissions with a slight increase in NO_x emissions, while increasing the higher useful compression ratio of a hydrogen supplemented fuel engine.

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7. APPENDIX 1

7.1. Engine Specifications

The technical details of the engine test rig are given below:

Make:	Kirloskar
Model:	AV1
Number of Cylinders:	One
Position:	Vertical
Arrangement of Valves:	Overhead
Cooling Medium:	Water
Cycle:	Four Stroke
Ignition:	Compression Ignition (before modification)
Combustion chamber form:	Cup in Piston (before modification)
Rated Power:	3.7 kW
Rated Speed:	1500 RPM
Bore:	80 mm
Stroke:	110 mm
Cylinder Capacity:	552.64 cc
Compression Ratio:	18.35 (before modification)
Dynamometer:	Electrical-AC Alternator
Cylinder Pressure:	By Piezo sensor, Range = 2000 psi (i.e.137.895 bar) (Ajay Sensors make)
Starting:	Auto start facility
Exhaust Gas Calorimeter:	Ind labs make
Orifice Diameter:	15 mm

This engine was converted for spark ignition and carburetion to suit ethanol fuel and a provision was made to induct hydrogen gas.

7.2. Parameters

Compression Ratio:	Made variable (with modified engine head) from 7 to 11
Fuels Used:	Ethanol, Hydrogen
Hydrogen Injection:	By induction method
Ignition (after modification):	Spark Ignition
Combustion Chamber form:	Disk-Shaped combustion chamber (with a flat piston (after modification) and chamber ceiling)
Computer Interface:	For Indicated Power (IP) measurement

7.3. Measurements

Ethanol Flow:	Measured using Pipette Reading for a known time
Hydrogen Flow:	By Rotometer (lpm)
Air Flow:	Measured by Manometer connected to the air tank
Loading:	Different Electrical loadings by switching off Air heaters (in steps of 20 %) in steps connected to dynamometer
Cylinder Pressure:	Measured using Piezo sensor which is fitted at top of the engine head, with cooling water circulation for the sensor. It is connected to Computer Interface to the PC
Water Flow:	By Water meter
Speed:	Measured using Proximity RPM sensor connected to Digital RPM Indicator

8. REFERENCES

1. The Hindu., "Ethanol-Blended Petrol in 9 States, 4 Union Territories", http://www.hinduonnet.com/thehindu/2003/02/02/stories/2003020202481100.htm, (2003).
2. Anoop Singh., Prasad, S., Joshi, "Ethanol as an Alternative Fuel from Agricultural, Industrial and Urban Residues", ***Resources, Conservation and Recycling Journal***, Vol. 50, (2007), 1-39.
3. Niven, R., "Ethanol in Gasoline: Environmental Impacts and Sustainability Review Article", ***Renewable and Sustainable Energy Reviews***, Vol. 9, (2005), 535-555.
4. Al Baghdadi, M. A. S., "Performance Study of a Four-Stroke Spark Ignition Engine working with both Hydrogen and Ethyl Alcohol as Supplementary Fuel", ***International Journal of Hydrogen Energy***, Vol. 25, (2000), 1005-1009.
5. Brinkman, N. D., "Ethanol Fuel-A Single Cylinder Engine Study of Efficiency and Exhaust Emissions", ***SAE Paper***, No. 810345, (1982).
6. Al-Hasan, M., "Effect of Ethanol-Unleaded Gasoline Blends on Engine Performance and Exhaust Emission", ***Energy Conversion and Management***, Vol. 44, (2003), 1547-1561.
7. Desoky, A. A. and El-Emam, S. H., "A Study on the Combustion of Alternative Fuels in Spark-Ignition Engines", ***International Journal of Hydrogen Energy***, Vol. 10, Issue 8, (1985).
8. Jamal, Y. and Wyszynski M. L., "On-Board Generation of Hydrogen-Rich Gaseous Fuel-A Review", ***International Journal of Hydrogen Energy***, Vol. 19, No. 7, (1994), 557-572.
9. Al-Baghdadi M. A. S. and Al-Janabi, H. A. S., "Improvement of Performance and Reduction of Pollutant Emission of a Four Stroke Spark Ignition Engine Fueled with Hydrogen-Gasoline Fuel Mixture", ***Energy Conversion Management Journal***, Vol. 41, No. 1, (2000), 77-91.
10. Das, L. M., "Exhaust Emission Characterization of Hydrogen Operated Engine System", ***International Journal of Hydrogen Energy***, Vol. 15, (1990), 815-833.
11. Mathur, H. B., Khajuria, P. R., "Performance and Emission Characteristics of Hydrogen Fuelled Spark Ignition Engine", ***International Journal of Hydrogen Energy***, Vol. 9, No. 8, (1984) , 729-735.
12. Mclean, W. J. and Homan, H. S., "Performance and Emissions of Hydrogen Fuelled Internal Combustion Engines", ***International Journal of Hydrogen Energy***, Vol. 1, (1976), 153-172.
13. Varde, K. S., "Combustion Characteristics of Small Spark Ignition Engines using Hydrogen Supplemented Fuel Mixtures", ***SAE Paper***, No. 810921, (1981), 1-7.