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Experimental investigation of performance and emission characteristics for the hydrogen and petrol fueled MPFI spark ignition engine

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Abstract — The demand of crude oils made researcher/automobile manufacturer look for alternative fuels which renewable and locally available. Hydrogen is differing from all the alternatives because of its outstanding properties and more than that it won't give any hazardous emissions. This paper shows the performance and emission comparison of hydrogen and petrol fuel experimentally. The exhaustive experiment was conducted on four cylinder, four stroke, manifold injected spark ignition engine by varying speeds of an engine. The result shows that improvement in brake specific fuel consumption and reduction in emissions for the hydrogen fuel but for brake power an brake mean effective pressure shows decline performance when compare to the petrol fuel.

Index Terms — Emission, Hydrogen, MPFI, Performance, SI engine,

1 Introduction

According to current availability of crude oil sources in the world, it won't be long lasting source to gain energy. On another hand the carbon emission of these oil sources making greenhouse effect over the atmosphere and which is more hazardous to our environment. By considering these problems, it is better to go for renewable energy sources which solve the problems. Hydrogen can be extracted from the renewable sources and will release zero emissions while burning. Hydrogen is called green gas and hopeful fuel for a future when compare to all alternatives [1], [2].

1.1 Hydrogen as fuel

Hydrogen burn with help of oxygen/air and leads to exothermic reaction so that it can be used as alternative fuel for automobiles. Many researchers started to work on hydrogen fuel because of its good properties like higher heating value, lower ignition energy, wide range of flammability and etc. Table 1 shows the properties of hydrogen and petrol fuel.

1.2 Hydrogen in SI engine

Currently running SI engine is designed for petrol operation but when hydrogen is replaced, minor modifications are required in fuel supply system, ignition timing and spark plug etc. While conducting hydrogen operation have to face inherent limitations such as backfire, preignition and rate of pressure rise. Even though it seems to be serious problems but it can be minimized or eliminated by changing the operation conditions [3], [4]. Back fire is the major problem for the users of hydrogen because its iginition energy and quenching distance are very low. This back fire can be eliminated by proper injection system for hydrogen. Das [6] studied different types of injection system for hydrogen and found that Timed Manifold Injection system (TMI) is the optimum technique to avoid abnormal combustion like pre-ignition, backfire etc. and good improvement in performance too.

TABLE 1

Fuel Properties [3], [5]

Property	Hydrogen	Gasoline
Density (kg/m³) at 27(°C) and 1 atm	0.082	730
Lower heating value (MJ/kg)	120	44.8
Volumetric energy content (kJ/m³)	3189	3704
Minimum quenching distance (mm)	0.64	2.0
Minimum ignition energy(mJ)	0.02	0.24
Flammability limits in air (vol%)	4–75	1.3-7.1
Stoichiometric air-to-fuel ratio (kg/kg)	34.2	14.6
Auto ignition Temperature (°C)	585	230-480
Octane number	130	87

1.3 So far work on hydrogen fuel

Because of hydrogen is a gaseous state at atmospheric condition and due to some properties, intially many researchers start to used as a secondary fuel. Shivaprasad et al. [7] Hydrogen can be added as various fractions to petrol fuel in high speed single cylinder SI engine and found that great improvement in BMEP (Brake Mean Effective Pressure) and BTE (Brake Thermal Efficiency) at 20% blend; UHC (Un-burnt Hydro-Carbon) and CO (Carbon-monoxide) emissions are reduced by adding hydrogen. Hydrogen addition to petrol engine not only improves the performance and also it will improve emission charactersitcs [8]. Ceviz et al. [9] varied hydrogen fraction in four cylinder SI engine results in improved BTE and Brake Specific Fuel Consumption (BSFC); UHC emissions

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decreased by 13% with increase in NOx (Oxides of Nitrogen). Solenoid actuated electronically controlled injection system is good for gaseous fuel. This is because of immediate response of switching valve avoid abnormal combustions. Das et al. [10] compared hydrogen performance with Comperesed Natural Gas (CNG) performance in modifed injection system in single cylinder engine and observed that BSFC and BTE are better for hydrogen when compared with CNG.

Some of the researchers are tried out with neat hydrogen fuel in engine by various induction techniques and got succeeded. Kahraman et al. [11] reduced 20MPa of compressed hydrogen to 3kPa by two regulators and by using of carburetor hydrogen supplied to the four cylinders SI engine and get the result as follow: increases power output and efficiencies relatively; NOx emission of hydrogen fuelled is 10 times lower than gasoline fueled. Yang et al. [12] studied the effect of ignition and injection timing in single cylinder SI engine in which fuel was inducted in manifold.

Research on hydrogen fuel in I.C. engine is given more importance due to its properties but, based on timed manifold hydrogen injection is less information is available. This paper explains how performance and emission parameters will vary for different speeds based on timed manifold injection.

2 Experimental Setup and Methodology

2.1 Setup Description

Experiment was conducted in Maruti Zen MPFI engine and detailed specifications of the engine and setup layout are shown in table 2.1 and figure 2.1 repectively. This engine was mounted on bed along with eddy current dynamometer and coupled. Load and speed of the engine are measured by load cell and speed sensors respectively which are mounted on dynamometer. Petrol consumption can measure by burette fixed near tank and stop clock; air consumption measured by pressure difference in manometer; exhaust gas analyzer used to detect the emission from the exhaust of the engine. MPFI (Multi Port/Point Fuel Injection) system used to inject fuel to the inlet manifold of an engine and this system controlled by ECM (Engine Control Module).

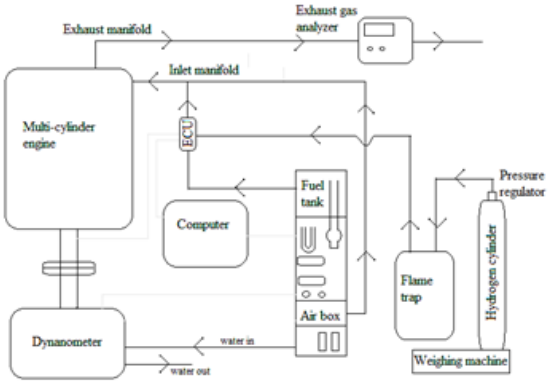


Fig 2.1 Schematic diagram experimental setup layout

Special ECU (Electronic Control Unit) was made and installed on the engine to inject hydrogen in the inlet manifold with the help of solenoid valve which switch from petrol to hydrogen fuel. Hydrogen consumption measured by placing cylinder on weighing machine and time taken measured stop clock. To avoid backfire from the engine to cylinder flame trap is installed in the fuel line. Commonly industrial hydrogen gas cylinder has a pressure of 150bar and it will be reduce to 2 to 6 bar according by using regulator. As hydrogen is very light gas so possibility of leaking so that leak test was done frequently.

TABLE 1

Fuel Properties

Description	Specification
Cycle	4
Number of cylinders	4
Bore	72mm
Stroke	61mm
Compression ratio	9.4:1
Swept volume	993 cc
Power	44.5kW @ 6000 rpm
Torque	78.5Nm @ 4500rpm
Fuel feeding	MPFI
Ignition timing	5° BTDC (petrol MBT)
Cooling type	Water cooled

2.2 Experimental Procedure

Initially engine should start with petrol and switch to hydrogen with the help of solenoid valve and ECU. After idle speed running of the engine for some time throttle was raised up to 25% of wide open throttle and kept it as constant. By adjusting the regulator in loading unit, speed of the engine varied such that from 2000 to 3000 rpm in the step of 250. This speed range is restricted because serious of back fire occurred below to 2000 rpm and above 3000 rpm. To evade from fluctuating reading this speed range was maintained.

Data are taken at various speeds at regular interval and enough time was given to attain stability. Each set of experiments was repeated three times and average of each parameter was considered.

3 Result and Discussion

According to the experimental procedure, experiments are done and required data are noted for analysis. Performance and emission results are plotted for hydrogen fuel and compared with baseline readings of the engine which was run by petrol. Throughout the following comparison the parameters behavior studied according to various speeds.

3.1 Performance Comparision

3.1.1 Brake Power (BP)

Fig 3.1 shows the variation of brake power with engine speed for petrol and hydrogen fuel. At 2500 rpm petrol shows little rise in brake power and it falls over increase in speed this because engine getting maximum torque near to that rpm. 46 to 54% of power drop for hydrogen when compare to petrol when increase in speed. This difference is due to the energy content on volume basis for hydrogen lesser than the petrol [11]. Moreover here hydrogen is operated at lean mixture to avoid pre-ignition and backfire.

3.1.2 Brake Specific Fuel Consumption (BSFC)

Fig 3.2 shows the BSFC comparison for petrol and hydrogen fuel. At higher speed hydrogen shows maximum reduction of 46% and minimum reduction of 39% at 2500rpm BSFC when compare to petrol. This difference is due to the lean mixture operation for hydrogen which is around 0.6 as equivalence ratio but petrol is operating nearly at stoichiometric mixture.

3.1.3 Brake Mean Effective Pressure (BMEP)

As the speed increases BMEP will decrases compare to petrol hydrogen massive lag in BMEP and this because of low energy content of hydrogen on volume basis [10]. Fig 3.3 shows nearly 46% of decrease in BMEP when the engine is operated with hydrogen compare to petrol fuel.

3.2 Emission Comparision

3.2.1 Oxides of Nitrogen (NO_x)

Fig 3.4 shows the NOx comparison for petrol and hydrogen fuel. Due to leaner operation for hydrogen heat produced in combustion chamber is less which leads to lesser NOx. By increasing speed NOx reduced gradually for both hydrogen and petrol fuels. Comparing the NOx level for hydrogen and petrol nearly 67% of reduction is found at 3000 rpm. At lower speed, load is higher which leads to higher in-cylinder temperature and resulted in lesser NOx of 34% at 2000 rpm.

3.2.2 Carbon monoxide (CO) and Unburnt HydroCarbon (UHC)

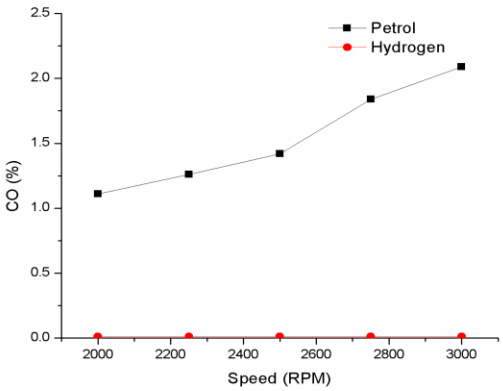


Fig 3.1 Variations of brake power with repect to speed

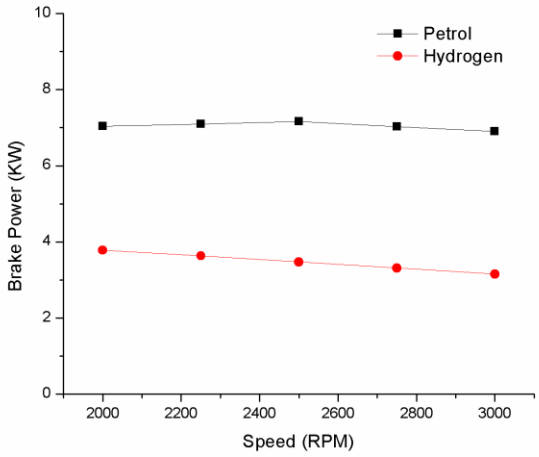
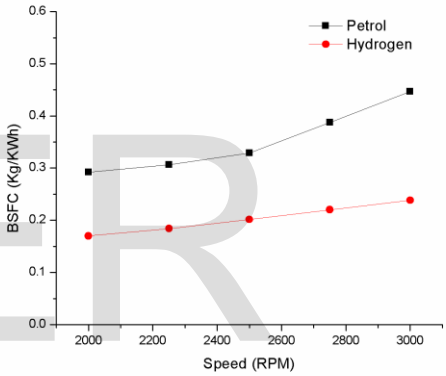


Fig 3.2 Variations of BSFC with repect to speed



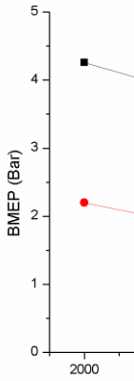


Fig 3.3 Variations of BMEP with repect to speed

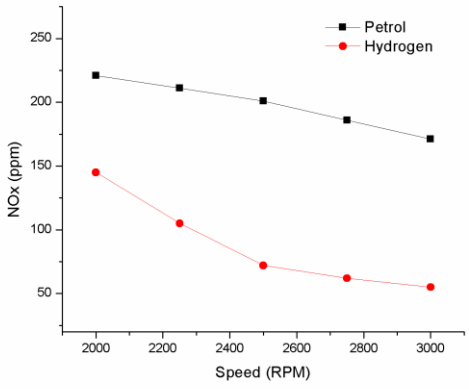


Fig 3.4 Variations of NO_x with repect to speed

Hydrogen is a clean fuel which does not have carbon elements in it. Fig 3.5 and Fig 3.6 shows the CO and UHC comparison respectively for hydrogen and petrol fuel. In CO and UHC emissions almost negligible amount is found during hydrogen fuel running. Even this because of little amount coolant oil is

leaked in combustion chamber during running. While ascending the speed CO and UHC emissions are increasing for petrol but for hydrogen CO emission is constant as 0.01%. But for UHC emission hydrogen shows little rise at higher speed and that too 3% of petrol UHC emission.

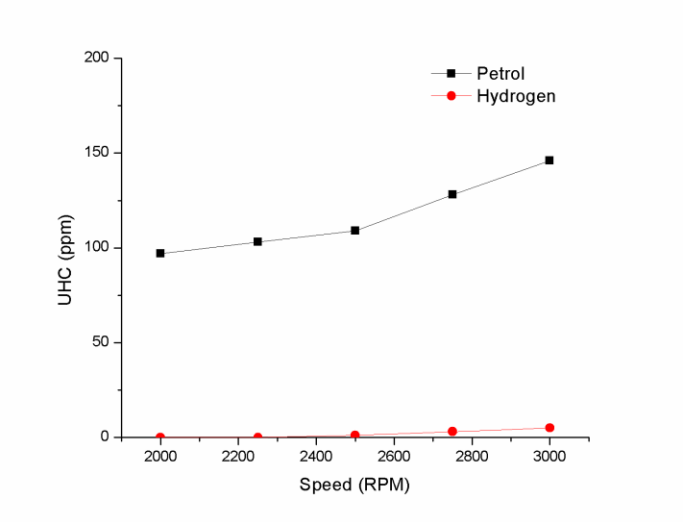


Fig 3.5 Variations of UHC with repect to speed

4 Conclusion

A conventional petrol engine adapted to hydrogen fuel and successful installation of ECU made for hydrogen is worked. Back fire occurrence is noted at lower speed below 2000 rpm and it can be rectified by varying the equivalence ratio. Improvement in brake power and BMEP of hydrogen are not satisfied when compare with petrol this because it has low energy content on volume basis. Lower BSFC and emission giving much relaxation while using with hydrogen this mainly due to low equivalence ratio nearly 0.6. Negligible emissions of CO and UHC are due to burning of lubricant oil in combustion chamber. Load taken by petrol is more compare to hydrogen which leads to high temperature caused to emit more NOx for petrol when compare to hydrogen.

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