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Analysis of Hydrogen Fuelled two Stroke Petrol Engine

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Abstract— *In the past history of IC engine design and development, hydrogen has been considered as a better replacement to hydrocarbon based fuels. Hydrogen gas combustion produces uncontaminated exhaust from spark ignition engine due to its desirable characteristics. Hydrogen for the experiment was produced by using fuel cells. This study examines the performance characteristics and emissions of a hydrogen fueled conventional spark ignition engine. Slight modifications are made for hydrogen feeding, which do not change the basic characteristics of the original engine. Comparison is made between the gasoline and hydrogen operation was discussed. The important pollutants from spark ignition engine like HC, CO, smoke and NOx are reduced due to hydrogen combustion. Certain remedies to overcome the backfire phenomena are attempted.*

Keywords— ***Two Stroke Petrol engine, Electrolysis, Hydrogen gas, Emissions, Backfire.***

I. INTRODUCTION

Basically both the fuels petrol and diesel is obtained from the crude oil (i.e.) petroleum. Now the problem is, its availability is decreasing day by day in bulk and insufficient for future decades. Hence an alternative fuel is essential to fight against scarcity. In term of long sight some alternative fuels are suggested and experimented by various manufacturing units with technicians, such alternative fuels are as follows. Hydrogen Gas, methyl alcohol, compressed Natural gas (CNG) and biodiesel. From experience since 1970 various researchers and engineers attempting to produce a best suitable and reliable way to replace existing fossil fuels such as gasoline, diesel etc. Hydrogen gas has been considered as a best alternative to gasoline in case of SI engine and diesel in case of CI engine [1-3]. When hydrogen tested on various SI engines as solely or partially at various parametric levels then in all experiments it reduces pollution levels drastically compared to that of SI engine which running purely on petrol [4]. Many trsrarchers are working to develop technologies that might efficiently exploit the potential of hydrogen energy for mobile uses. The attraction of using hydrogen as an energy currency is that, if hydrogen is prepared without using fossil fuel inputs, vehicle propulsion would not contribute to carbon dioxide emissions [5-8]. The drawbacks of hydrogen use are low energy content per unit volume, high tank age weights, the storage, transportation and filling of gaseous or liquid hydrogen in vehicles, the large investment in infrastructure that would be required to fuel vehicles, and the inefficiency of production processes [9-10]. Buses, trains, canal boats, motorcycles, ships, airplanes, submarines, and rockets can already run on hydrogen, in various forms. NASA uses hydrogen to launch Space Shuttles into space. There is even a working toy model car that runs on solar power, using a regenerative fuel cell to store energy in the form of hydrogen and oxygen gas. It can then convert the fuel back into water to release the solar energy [11-13]. The current land speed record for a hydrogen-powered vehicle is 286.476 mph (461.038 km/h) set by Ohio State University's Buckeye Bullet 2, which achieved a "flying-mile" speed of 280.007 mph (450.628 km/h) at the Bonneville Salt Flats in August 2008. For production-style vehicles, the current record for a hydrogen-powered vehicle is 333.38 km/h (207.2 mph) set by a prototype Ford Fusion Hydrogen 999 Fuel Cell Race Car at Bonneville Salt Flats in Wend over, Utah in August 2007. It was accompanied by a large compressed oxygen tank to increase power. Honda has also created a concept called the FC Sport, which may be able to beat that record if put into production [14-17]. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are used to power fuel cell vehicles, including automobiles, buses, forklifts, airplanes, boats, motorcycles and submarines. There are many types of fuel cells, but they all consist of an anode (negative side), a cathode (positive side) and an electrolyte that allows charges to move between the two sides of the fuel cell. Electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use [18,19]. The energy efficiency of a fuel cell is generally

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between 40-60%, or up to 85% efficient if waste heat is captured for use [20]. In this work hydrogen gas produced by using electrolysis process in fuel cell and it was fed as fuel for two stroke spark ignition engine. Comparison is made between the petrol and hydrogen gas operation was discussed.

II. EXPERIMENTAL SETUP AND TEST PROCEDURE

Fuel Cell

The Fuel cells are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is created, which can be used to power electrical devices, normally referred to as the load. At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide. A block diagram of a fuel cell shown in figure 2.

The most important design features in a fuel cell are,

- The electrolyte substance. The electrolyte substance usually defines the type of fuel cell.
- The fuel that is used. The most common fuel is hydrogen.
- The anode catalyst, which breaks down the fuel into electrons and ions. The anode catalyst is usually made up of very fine platinum powder.
- The cathode catalyst, which turns the ions into the waste chemicals like water or carbon dioxide. The cathode catalyst is often made up of nickel but it can also be a nano material-based catalyst.

A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors:

- Activation loss
- Ohmic loss (voltage drop due to resistance of the cell components and interconnections)
- Mass transport loss (depletion of reactants at catalyst sites under high loads, causing rapid loss of voltage).

To deliver the desired amount of energy, the fuel cells can be combined in series and parallel circuits, where series yields higher voltage, and parallel allows a higher current to be supplied. Such a design is called a fuel cell stack. The cell surface area can be increased, to allow stronger current from each cell.

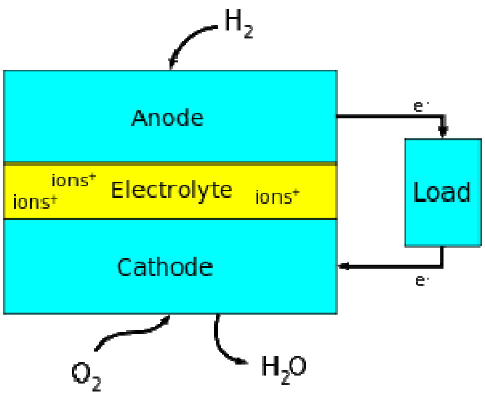

***Fig. 2** Block Diagram of a Fuel Cell*

Hydrogen Electrolysis

Hydrogen electrolysis is the process of spitting water into Hydrogen gas and Oxygen gas. The Hydrogen gas can then be used as fuel either by being burnt in an engine or reacted in a fuel cell. This is the process that so-called water powered cars rely on for their energy. No car can use wateras a fuel, but a car can be made to run only on Hydrogen, meaning that its exhaust gas will be just water vapour. The rods inserted in the water are calledelectrodes. The one where electrons come out is called the anode and the one where the electrons go in is called the cathode. The reactions that occur at these electrodes are different and this difference is caused by the removal or supply of electrons. As is the case for other oxidation reduction reaction, the reaction where electrons are removed is called an oxidation reaction, and the reaction where electrons are supplied is called a reduction reaction.

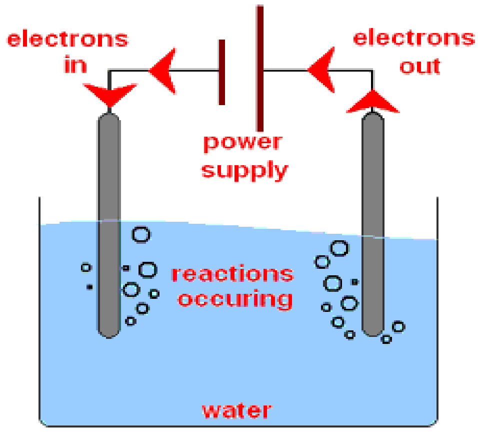

Fig. 3 Hydrogen Electrolysis

The anode reaction turns water into Oxygen gas, protons (H+) and electrons. This is shown below. The cathode reaction consumes electrons and turns water into Hydrogen gas and hydroxide ions.

Engine Setup

A conventional single cylinder SI engine was adapted to operate on gaseous hydrogen. Compressed gas at 220 bar in steel bottles was introduced to the engine by external mixing. The first stage regulator drops the pressure to 5 bar to a copper gas supply line where a flowmeter is installed. The second stage regulator supplies hydrogen to the mixing apparatus installed on the inlet manifold. Spray nozzles for water induction are placed approximately 4 cm away from the inlet valves. Ignition timing was set to 23° before TDC and fixed. The fuel flow rate is obtained by the flow meter and the airflow rate is obtained on the volumetric basis. The AVL smoke meter is used to measure the smoke density. AVL five-gas analyzer is used to measure the rest of the pollutants. The experimental setup is indicated in Figure 4 and engine specifications are given in table 1.

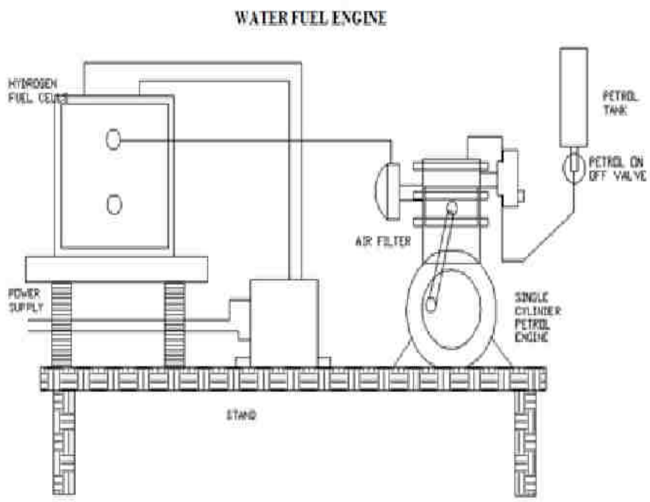

***Fig. 4** Experimental Setup*

Table 1 Technical Specifications of the Engine

Type	Two stroke, air cooled spark Ignition Engine
No. of cylinder	1
Cubic capacity	59.3 cm^3
Compression ratio	10:1
Cylinder bore	42 mm
Stroke:	43 mm
Rated output	2.2 kW(3.0 HP) @ 5400 rpm

III. RESULTS AND DISCUSSION

The operation of the engine was found to be very smooth throughout the rated load, without any operational problems for the hydrogen fuel. In the present section, the performance attributes such as brake thermal efficiency, indicated thermal efficiency and mechanical efficiency, and the emission characteristics such as NOx, CO and HC are plotted against brake power.

Performance

Comparison of brake thermal efficiency of gasoline and hydrogen operation is shown in Figure 5. Obviously hydrogen has a higher brake thermal efficiency. It is known for petrol engines that they show their effective efficiency at greater part loads whereas hydrogen can operate even at low part loads with better efficiency. Figure 6 shows the variation of mechanical efficiency for hydrogen fuel and petrol fuel.

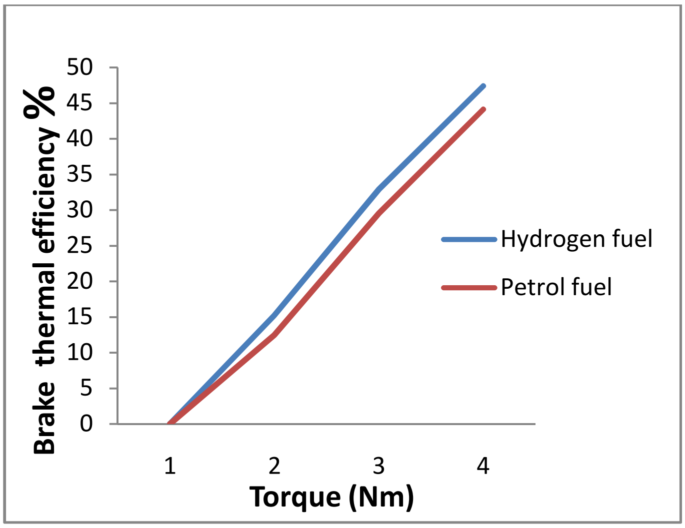

***Fig. 5** Brake Thermal Efficiency against Torque*

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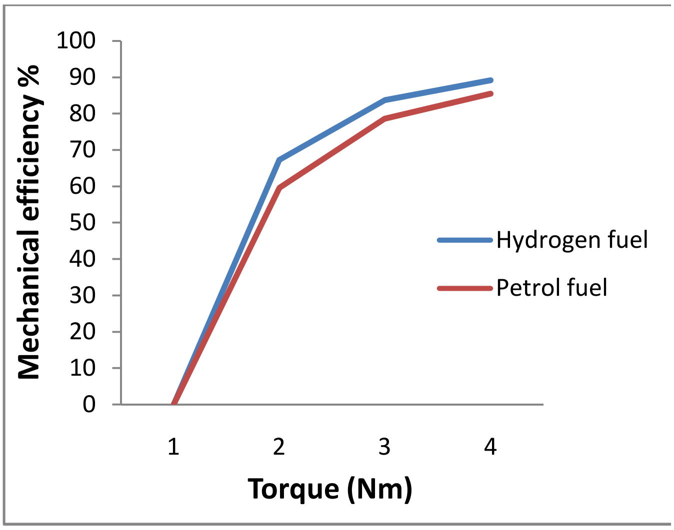

***Fig. 6** Mechanical Efficiency against Torque*

Emissions

Hydrocarbon (HC)

During combustion the temperature inside the cylinder is extremely high. As the piston expands, this heat evaporates a certain amount of the oil. Observing Figure 7, the contribution of the evaporated and incompletely burned oil to the overall emission can be guessed. Gasoline is a long-chain hydrocarbon and when not completely burned, breaks up into short chain hydrocarbons. Hydrogen is a gaseous fuel and does not conventional fuels. Better lubricating characteristics and longer engine life is obtained. At low speed the gasoline engine is choked and therefore more unburnt hydrocarbons are present in the exhaust gases. The only hydrocarbon emission from the hydrogen engine is due to the above mentioned oil film evaporation.

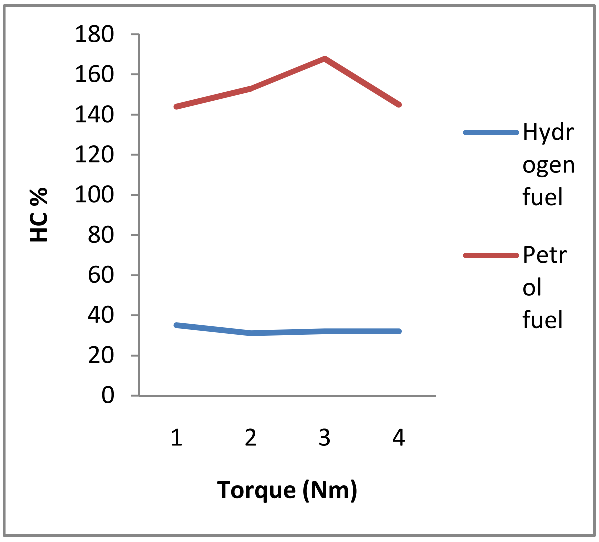

***Fig. 7** Hydrocarbon Emission against Torque*

Carbon Monoxide (CO)

Carbon monoxide emissions are due to incomplete combustion of fossil fuels. It is expected that the hydrogen engine has zero carbon monoxide emissions since hydrogen is a carbon-free fuel. As the results in Figure 8 show, some amount of carbon monoxide is still present even with hydrogen. This is due to the burning of the lubricating oil film inside the cylinder. As speed increases, these emissions tend to diminish. For hydrogen there is practically no emission, only very slight values again due to combustion of the lubricating oil film.

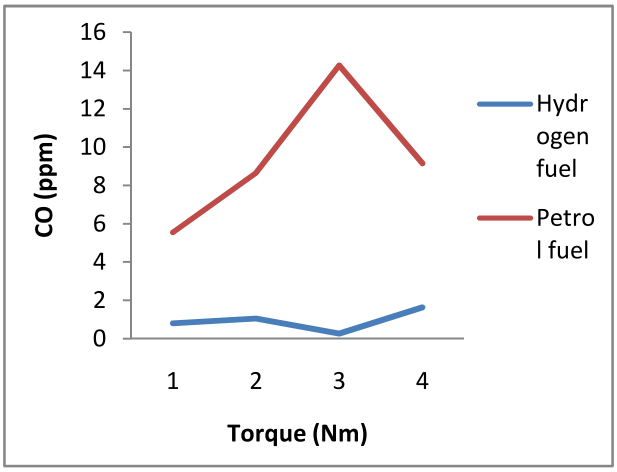

***Fig. 8** Carbon monoxide against Torque*

Oxides of Nitrogen (NOx)

Figure 9 portrays the NOx levels of both engines in ppm. Considerable decrease in NOx emissions is observed with hydrogen operation. The cooling effect of the water inducted plays an important role in this reduction. Also operating the engine with hydrogen kept the emissions low compared with petrol fuel.

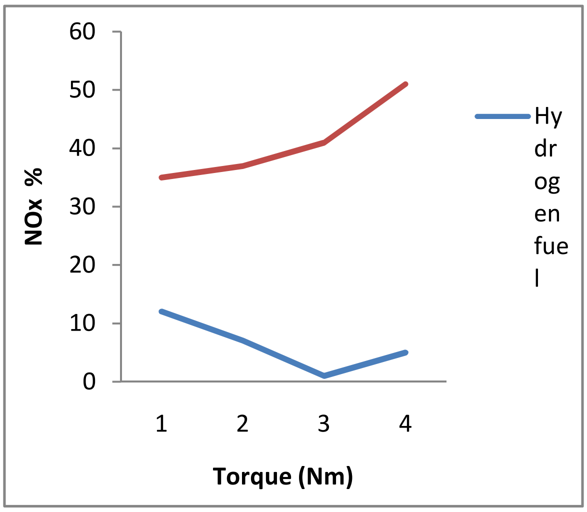

***Fig. 9** Oxides of nitrogen against Torque*

IV. CONCLUSION

It is a clear evidence that addition of hydrogen along with petrol can results in increase in the power of the engine or increase in mileage. Moreover the various emissions normally produced from IC engines can be reduced.

- The rake thermal efficiency and mechanical efficiency for hydrogen fuel was higher than gasoline fuel.
- NOx emissions were about 10 times lower than with gasoline operation. CO and HC emissions were almost negligible as expected. Traces of these emissions were present because of the evaporating and burning lubricating oil film on the cylinder walls.

Hydrogen has the potential to achieve problem-free operation in IC engines. The future advances depend on whether hydrogen can be obtained abundantly and economically.

Nomenclature

CO	Carbon monoxide, %
HC	Hydrocarbon, ppm
NOx	Oxides of nitrogen, %
rpm	Revolution per minute
η_{mech}	Mechanical efficiency, %
η_{BTE}	Brake thermal efficiency, %
TDC	Top dead centre

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