Performance Analysis of hydrogen Fueled Internal Combustion Engine

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Abstract— In the history of internal combustion engine development, hydrogen has been considered at several phases as a substitute of hydrocarbon-based fuels. Starting from the 70's, there have been several attempts to convert engines for hydrogen operation. Together with the development in gas injector technology it has become possible to control precisely the injection of hydrogen for safe operation. Here we are using stainless steel plate as electrode in the electrolytic cell, the electrolyte being water and NACL salt. The electrolytic cell we used is a 12V battery case made of plastic. The cross sectional layers are cut such that the stainless steel plate fix in the battery case. The plates are separated by very small distance and the plates are given parallel holes for electron flow to be uniform. The power source to the kit is provided by a 12V and 9Ams battery. We used a transparent tube to supply the hydrogen produced in the kit to the air hose tube of our motor cycle. In order to keep the battery charged we used two 6 Amp diode to power the battery while running. There is a separate switch to power the kit and to protect the battery from getting drained. The stainless steel plates are of 50cm length, 25cm height, 2 millimeter thickness. The battery case can hold up to 5 liters of electrolyte. The use of hydrogen with petrol to power the vehicle has resulted in increase in vehicle mileage, accelerating speed with most important task of reduction in exhaust emission.

Keywords*:* NACL, hydrogen, solar, wind

I. INTRODUCTION

Fossil fuels i.e., petroleum, natural gas and coal, which meet most of the world's energy demand today, are being depleted rapidly. Also, their combustion products are causing global problems, such as the greenhouse effect, ozone layer depletion, acid rain sand pollution, which are posing great danger for our environment, and eventually, for the total life on our planet. Many engineers and scientist agree that the solution to all of the globalproblems would be to replace the existing fossil fuel system with the clean hydrogen energy system.Hydrogen is a very efficient and clean fuel. Its combustion will produce no greenhouse gases, no ozone layer depleting chemicals, and little or no acid rain in gradient sand pollution.Hydrogen, produced from renewable energy (solar, wind, etc.) sources, would result in a permanent energy system which would never have to be changed.

Fossil fuels possess very useful properties not shared by non-conventional energy sources that have made them popular during the last century. Unfortunately, fossil fuels are not renewable. In addition ,the pollutants emitted by fossil energy systems(e.g.CO, CO_2, C_nH_m, So_x, No_x, radioactivity, heavy metals, ashes, etc.) are greater and more damaging than those that might be produced by a renewable based hydrogen energy system. Since the oil crisis of 1973, considerable progress has been made in the search for alternative energy sources. A long term goal of energy research has been the seek for a method to produce hydrogen fuel economically by splitting water.

Lowering of worldwide CO_2 emission to reduce the risk of climate change (greenhouse effect) requires a major restructuring of the energy system. The use of hydrogen a energy carriers a long term option to reduce CO_2 emissions. However, at the present time, hydrogen is not competitive with other energy carriers.Global utilization of fossil fuels for energy needs is rapidly resulting in critical environmental problems throughout the world. Energy, economic and political crises, aswell as the health of humans, animals and plant life are all critical concerns. There is an urgent need of implementing the hydrogen technology.

A worldwide conversion from fossil fuels to hydrogen would eliminate many of the problem sand their consequences. The production of hydrogen from non-polluting sources is the ideal way.Solar hydrogen is a clean energy carrier. Electrolytic hydrogen is made from water and becomes water again Hydrogen obtained from solar energy is ecologically responsible along it sent ire energy conversion chain. At only one link of the chain can apollutant, nitrogen oxide, arise; and this occurs only if the hydrogen is not combined with pure oxygen, but using air as an oxidant, such as in reciprocating piston engines or gas turbines of automobiles or aircraft. At the high reaction temperatures which arise in such places, the oxygen and nitrogen in the air can combine to form nitrogen oxide.

The economies of rich nations and the lifestyle of most of the residents depend on cars andlight trucks. Thesevehicles contribute most of the carbon monoxide (CO), carbondioxide(CO_2), volatile organic compounds (hydrocarbons, HC), and nitrogen oxides(No_x) emitted in cities. It is clear that motor vehicles are important to the economy and lifestyle. Importance goes well beyond the direct consumer expenditures and indirect (support) expenditures, such as roads, suburbs, oil wells, refineries, and service stations.

Hydrogen has long been recognized as a fuel having some unique and highly desirable properties, for application as a fuel in engines. It is the only fuel that can be produced entirely from the plentiful renewable resource water, though the expenditure of relatively much energy. Its combustion in oxygen produces unique lonely water but in aerials produces some oxides of nitrogen. These features make hydrogen an excellent fuel to potentially meet the ever increasingly strict environmental controls of exhaust emissions from combustion devices, including the reduction of greenhouse gas emissions. Hydrogen as are new able fuel resource can be produced through the expenditure of energy to replace increasingly the depleting sources of conventional fossil fuels. A brief statement and discussion of the positive features of hydrogen as a fuel and the associate delimitations that are raising difficulties in its wide application as an engine fuel are both necessary and needed.

These limitations that hinder its wide spread application as an engine fuel are primarily related to its production, storage, portability, transport and purity. These limitation scan be considered to be farm or serious than those facing the current and future applications of other fuels, including natural gas.The use of hydrogen as an engine fuel has been attempted on very limited basis with varying degrees of success by numerous investigators over many decades, and much information about their findings is available in the open literature. However, these reported performance data do not display consistent agreement between various investigators. There is also a tendency to focus on results obtained in specific engines and over narrowly changed operating conditions. Moreover, the increasingly greater emphasis being placed on the nature of emissions and efficiency consideration so makesmuch of the very early work fragmentary and mainly of historical value. Obviously, there is a need to be aware of what has been achieved in this field while focusing both on the attractive features as well as the potential limitations and associated draw backs that need to be overcome for hydrogen to become a widely accepted and used fuel for engine applications. Also, there is a need to indicate practical steps for operating and design measures to be developed and incorporated for hydrogen to achieve its full potential as an attractive and superior engine fuel.

II. ANOTE ON HYDROGEN

Hydrogen is an outstanding fuel in many ways. Its energy content per unit weight is nearly three times that of hydrocarbons (which is why it is used in rocket propulsion systems), it has outstanding electrochemical properties for use in fuel cells, and is an extremely clean burning fuel.

On the other hand, since hydrogen is not a fuel per se because it does not exist in nature in significant quantities. Rather, hydrogen is an energy carrier that must be made from something else, thus cost effective production of hydrogen from energy “feedstock’s” (coal, petroleum, nuclear energy, solar energy, biomass, etc.) is a very substantial barrier to any hydrogen-based economy. Additionally, while hydrogen is indeed very clean-burning, the environmental cost of producing the hydrogen must also be considered.

Hydrogen is also easy to burn in internal combustion engines, even in very lean, low-temperature flames, but also has much more serious Figure. Ballard HY-80 fuel cell engine explosion hazards than hydrocarbons. Also, being a very small molecule, it leaks out of tanks and through valves much more readily than other pressurized-gas fuels such as natural gas.

In addition to the production and safety issues associated with hydrogen, its storage on a vehicle is extremely problematic. The only known weight-effective way of storing hydrogen at atmospheric pressure is as a cryogenic liquid at -424°F, though even in this case the density of the liquid is very low, 14 times less than that of water, and certainly cryogenic hydrogen is both difficult and dangerous to manufacture, transport and store, hence its use only in specialized applications such as rocket propulsion.

As a compressed gas, even with optimistic estimates of the tank weight assuming lightweight, high-strength materials, and the weight of the tank will be about 15 times that of the hydrogen itself.

Hydride solutions such as sodium boron hydride (NaBH4) in water produce hydrogen through the chemical reaction but even in this case the mass of the solution is 9.25 times that of the mass of the hydrogen produced. Hydrogen can also be stored in the interstitial spaces between palladium atoms, but the weight of the palladium is about 160 times that of the hydrogen produced.

On the other hand, long chain saturated hydrocarbons have the chemical formula (CH2) and thus the weight of the hydrocarbon is 7 times that of the hydrogen produced, which is better that that of the other storage methods described above. In other words, by far the best way to store hydrogen is to attach it to carbon atom sand make hydrocarbons, even if the carbon is not used as an energy source! And if the carbon is also used, the energy release increases from about 16, 40,000 Joules per kilogram to 43,000,000 Joules per kilogram– more than double.

III. HYDROGEN AS AN ENGINE FUEL

There are number of unique features associated with hydrogen that make it remarkably well suited in principle, to engine applications. Some of these most notable features are the following:

Hydrogen, over wide temperature and pressure ranges, has very high flame propagation rates within the engine cylinder in comparison to other fuels. These rates remain sufficiently high even for very lean mixtures that are well away from the Stoichiometric mixture region. The associated energy release is also so fast that the combustion duration, tends to be short and contributes towards producing high-power output efficiencies and high rates of pressure rise following spark ignition.

The lean operation all limit mixture in a spark ignition engine when fuelled with hydrogen is very much lower than those for other common fuels. This permits stable lean mixture operation and control in hydrogen fueled engines.

The operation on lean mixtures, in combination with the fast combustion energy release rates around top dead center associated with the very rapid burning of hydrogen–air mixtures results in high-output efficiency values. Of course, such lean mixture operation leads simultaneously to a lower power output for any engine size.

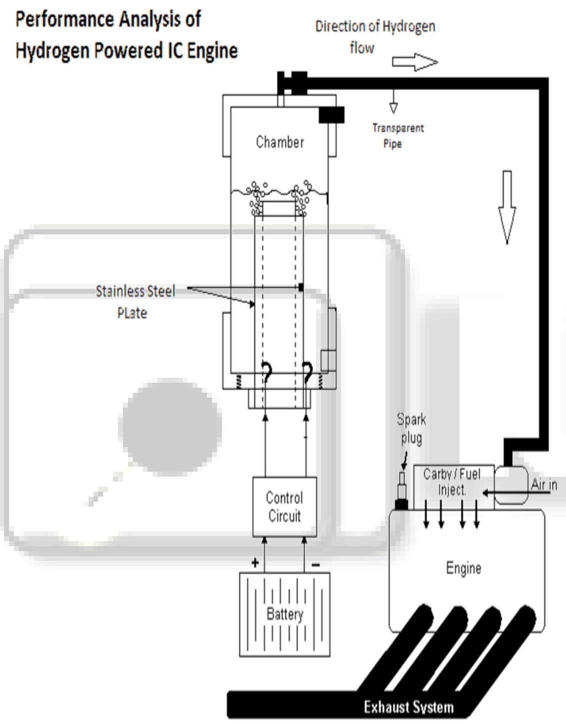
One of the most important features of hydrogen engine operation is that it is associated with less undesirable exhaust emissions than for operation on other fuels. As far as the contribution of the hydrogen fuel to emissions, there are no un burnt hydrocarbons, carbon monoxide, carbon dioxide, and oxides of sulfur, smoke or particulates. The contribution of the lubricating oil to such emissions in well-maintained engines tends to be rather negligible. Only oxides of nitrogen and water vapor are the main products of combustion emitted. Also, with lean operation the level of NO_X tends to be significantly smaller than those encountered with operation on other fuels.

The fast burning characteristics of hydrogen permit much more satisfactory high-speed engine operation. This would allow an increase in power output with a reduced penalty for lean mixture operation. Also, the extremely low boiling temperature of hydrogen leads to fewer problems encountered with cold weather operation.

Varying the spark timing in hydrogen engine operation represents an unusually effective means for improving engine performance and avoids an incidence of knock.

Because pure hydrogen does not occur naturally, it takes a substantial amount of energy to manufacture it. There are different ways to manufacture it, such as electrolysis and steam-methane reforming process. In electrolysis, electricity is run through water to separate the hydrogen and oxygen atoms. This method can use wind, solar, geothermal, hydro, fossil fuels, biomass, and many other resources. Obtaining hydrogen from this process is being studied as a viable way to produce it domestically at a low cost.Before employing hydrogen directly to the combustion chamber the parts of IC engines needs a little change.

IV. CIRCUIT DIAGRAM



V. HYDROGEN AS AN FUEL IN ICE

All internal combustion engines depend on the exothermic chemical process of combustion or burning: the reaction of a fuel with the ambient air oxygen taking place inside the engine's combustion chamber.

While most common fuels used today are made up of hydrocarbons and are derived from crude oil (such as diesel, gasoline and liquefied petroleum gas) or from natural gas, also liquid and gaseous biofuels (such as ethanol) or even hydrogen (either in compressed form as CGH2 or in liquefied form such as LH2) can be used.

Using hydrogen as a fuel in internal combustion engines means benefiting from a number of advantages that hydrogen provides in comparison to conventional fuels:

When using hydrogen in ICE, exhaust gas emissions are extremely low. The values are for nitrogen oxide (NO X) about 0.2 g/kWh, for hydrocarbons (HC) 0.04 g/kWh (0.46) and for particulate matter (PM) less than 0.005 g/kWh (0.02). Carbon monoxide emissions remain below measurable limits.

No greenhouse gases are emitted whatsoever, due to the absence of carbon material.

Depending on the fuel production paths, hydrogen ICEs can be operated fully independently of fossil fuel.

Hydrogen internal combustion engines are typically based on ICEs designed for the combustion of natural gas (CNG). However, substantial research and fundamental adjustments are necessary to make them powerful components in powerful vehicles. But as most components are identical with those used in conventional diesel engines, the costs at present remain much lower than those for fuel cell propulsion systems.

VI. THEORETICAL CALCULATION ON PRODUCTION OF HYDROGEN GAS

As everyone knows water has two molecules of hydrogen and one molecule of oxygen here is the theoretical calculation on production of hydrogen gas

2 H2O --> 2 H2 + O2, so 2 moles of water produces 2 moles of H2 gas and 1 mole ofO2.1 L of water at 21 °C has density 0.998 kg/L, molar mass 18.0153 g/mol, so 55.40 moles. We will produce 55.40 moles H2 and 27.70 moles of O2.

At 1 atm, 0 °C, 1 mole of ideal gas has volume of 22.414 L, at 21 °C, 24.14 L. Thus about 669 L O2 and 1337 L of H2.

The 55.4 mol H2 would require 110.8 mol of electrons. At the Faraday constant of 96485.34 A·s/mol, about 10.69 MA·s. The energy gap is 1.23 V so 13.15 MJ, at an infinitesimal rate but reversible reaction. Practical electrolysis cells need to be overdriven at about 1.75 V per cell (about 70% efficiency) so about 18.7 MJ to produce 55.4 mol of H2 about 110.8 g, and what we get from electrolysis of 1 L of water.

VII. AIR FUEL RATIO

No of N_2 in air =Moles of O_2*(79% of N_2 in air/21% of O_2 in air)

=1 moles ofO_2*(79% of N_2 in air/21% of O_2 in air)

Number of moles in air = Moles of O_2+moles of N_2

=1+3.762

=4.762

Weight of O_2 = 1 mole of O_2 x 32 g/mole

=32g

Weight of N_2 = 3.762 moles of N_2*28g/mole

=105.33g

Weight of air = weight of O_2+weight of N(1)

=32+105.33

=137.33g

Weight of H = 2 moles ofH_2*2g/mole

=4g

=3.762g/mole

Stoichiometric air/fuel ratio for hydrogen and air is

A/F based on mass = Mass of air/mass of fuel

=137.33g/4g

=34:33:1

To find the percentage of hydrogen produced, the theoretical calculation is made as follows.

%of H_2 = Volume of H_2/total volume

=Volume of H_2/(volume of H_2+volume of air)

=2/(4.762/2) =29.6%

- As these calculations show, the Stoichiometric or chemically correct A/F ratio for the complete combustion of hydrogen in air about 34:1 by mass
- This means that for complete combustion, 34 pounds of air are required every pound of hydrogen
- This is much higher than the 14:7:1 A/F ratio required for gasoline.
- Since hydrogen is a gaseous fuel at ambient conditions it displaces more of the combustion chamber other than liquid fuel.
- Consequently less of the combustion chamber can be occupied by air.
- At Stoichiometric conditions ,hydrogen displaces about 30% of the combustion chamber ,compared to about 1 to 2% for gasoline

VIII. CONCLUSION

A conventional SI engine could be used to operate using hydrogen as a fuel. To achieve this, some modifications should be done on the engine to be set to operate on hydrogen. Hydrogen gas has issues on safety because it is very prone to explosion if it gets accumulated more in combustion chamber of engine and there is a problem in storing hydrogen in the storage tank as it has the chance of leaking into the atmosphere.

Hydrogen has to be produced by splitting hydrogen molecules from water using electrolysis. So, we need some additional devices to produce hydrogen gas. This may increase the production cost of hydrogen fueled engine. This engine has both the advantages and disadvantages. Since hydrogen fuel has no carbon, there will be no HC and CO emissions but it has fewer amounts of NOX emissions when compared to fossil fuels as it is mixed with atmospheric air.

All other fossil fuels are non-renewable resources, these fuels will be depleted but hydrogen is always available abundantly since it is renewable. So, Hydrogen fuel is considered as a fuel for future. But, the future advances depend on whether hydrogen can be obtained abundantly andeconomically. To be exact, hydrogen has the potential to achieve problem-free operation in IC engines. Some other important aspects of using hydrogen in IC engine.