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Advancement of Hydrogen as a Fuel in 4-Stroke Internal Combustion Engine

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ABSTRACT

Hydrogen provides a pathway for energy diversity. This Research paper examines the performance characteristics and emissions of a hydrogen fuelled 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 and engine design changes are discussed. Certain remedies to overcome the backfire phenomena are attempted. In advancement of fuel, petrol is combined with hydrogen produces power and thereby increasing efficiency. Active research in the development of hydrogen-fuelled low-emission. Use of Hydrogen for producing mechanical energy by extracting it from the water.

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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 rains and pollution, which are posing great danger for our environment, and eventually, for the total life on our planet. Many engineers and scientists agree that the solution to all of these global problems would be to replace the existing fossil fuel system with the clean hydrogen energy system. In the history of internal combustion engine development, hydrogen has been considered at several phases as a substitute to 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. Since the fuel cell needs certain improvements before it is widely used in vehicles, the conventional internal combustion engine is to play an important role in the transition 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 ingredients and pollution. Hydrogen, produced from renewable energy (solar, wind, etc.) sources, would result in a permanent energy system which would never have to be changed.

Hydrogen has long been recognized as a fuel having some unique and highly desirable properties, for application as a fuel in engines (King RO, Rand M. 1955). It is the only fuel that can be produced entirely from the plentiful renewable resource water, though through the expenditure of relatively much energy. Its combustion in oxygen produces uniquely only water but in air it also 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 green house gas emissions. The use of hydrogen as an engine fuel has been attempted on very limited basis with varying degrees of success by numerous investigators 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 considerations often makes much 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 drawbacks 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.

“The hydrogen engine” [3]. In the early years of the development of internal combustion engines hydrogen was not the "exotic" fuel that it is today[5]. Water splitting by electrolysis was a well known laboratory phenomenon. Otto, in the early 1870s, considered a variety of fuels for his internal combustion engine, including hydrogen. He rejected gasoline as being too dangerous. Later developments in combustion technology made gasoline safer.

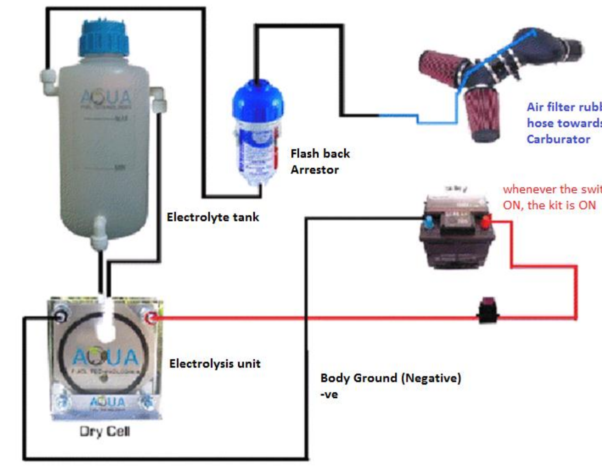
During World War I hydrogen and pure oxygen were considered for submarine use because the crew could get drinkable water from the exhaust. Hydrogen was also considered for use in powering airship engines. The gas used for buoyancy could also be used for fuel. Even if helium were used to provide lift, hydrogen gas could be used to supply additional buoyancy if stored at low pressure in a light container.After World War II, King found the cause of preignition to be hot spots in the combustion chamber from the high temperature ash, the residue from burned oil and dust. He traced backfire to high flame velocity at high equivalency ratios.[15] M.R. Swain and R.R. Adt at the University of Miami developed modified injection techniques with a 1,600 cm3 Toyota engine with a compression ratio of 9:1. The Illinois Institute of Technology converted a 1972 Vega using a propane carburetor. Converting to propane fuel utilizes similar technology as hydrogen. Roger Billings, in collaboration with Brigham Young University, entered a hydrogen-converted Volkswagen in the 1972 Urban Vehicle Competition. The vehicle won first place in the emissions category over 60 other vehicles even though the peak emissions were greater than for other hydrogen powered vehicles elsewhere. Nitrous oxides exceeded levels obtained by other experimenters using direct injection. Robert Zweig converted a pickup truck to hydrogen power in 1975.trucks in public exhibits. “Hydrogen a Commercial fuel for internal combustion engines and other purposes” [7]. It was Rudolf A. Erren who first made practical the hydrogen-fueled engine in the 1920s and converted over 1,000 engines. His projects included trucks and buses. After World War II the allies discovered a submarine converted by Erren to hydrogen power. Even the torpedoes were hydrogen powered. In 1924 Ricardo conducted the first systematic engine performance tests on hydrogen.[10] He used a one cylinder engine and tried various compression ratios. At a compression ratio of 7:1, the engine achieved a peak efficiency of 43%. At compression ratio of 9.9:1, Burnstall obtained an efficiency of 41.3% with an equivalency ratio range of 0.58-0.80.

The Brookhaven National Laboratory converted a Wankel (rotary) engine to hydrogen. It worked better with hydrogen than conventional engines because its combustion chamber enhances the emission of hydrocarbon pollutants. Mazda has converted one of their rotary engine cars to run on hydrogen. The unique design of the rotary engine keeps the hydrogen and air separate until they are combined in the combustion chamber. The Indian Institute of Technology tested spark ignition engines converted to hydrogen and has come to the following conclusions: Hydrogen permits a wide range of fuel-air mixtures. Very little throttling is needed. The fuel-air ratio and the amount of fuel are varied instead. Conversion requires higher compression ratios like up to 11:1. Hydrogen is 30 to 50% more efficient than gasoline. The Indian researchers also reached some conclusions regarding the use of hydrogen in addition to diesel fuel in diesel engines. They reduced the compression ratios from 16.5:1 to 14.5:1. Because of hydrogen's high rate of combustion only a small amount should be used mixed with diesel fuel. A high ignition temperature is necessary: 585 °C. The more hydrogen is added to the fuel mix the lower is the level of toxic emissions. The researchers added a water injection system to lower the combustion temperature and nitrous oxide production. The ratio was 4:1, by weight, of water to hydrogen. Daily fuel consumption was 1.4 kg of hydrogen and 5.4 kg of water. Water was injected as a fine mist directly into the manifold of the engine. This reduced backfiring into the manifold and boosted power.

Working of HHO Generator

HHO is composed of two separate elements of Water, consisting of two atoms of Hydrogen (H) and one atom of Oxygen (O), thus H2O becomes HHO. (A gaseous state). The most abundant element in the known Universe is Hydrogen, which is the volatile part of this amazing fuel. Oxygen does not burn, but it does support combustion.

Figure:01

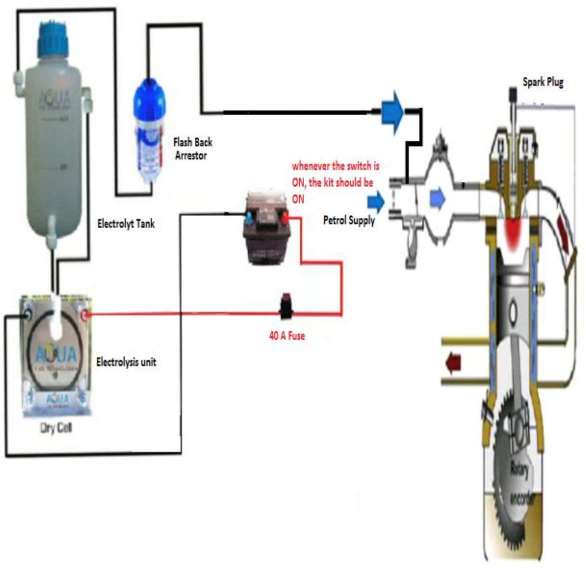


Line Diagram of HHO Generator

The technology that is used to extract the two elements from water is known as Electrolysis. Electrolysis of water has been used for experimentation and other industrial processes for over a hundred years .The HHO fuel systems used today are used primarily as a supplemental fuel rather than a replacement for gasoline. The electrolyser, a device for producing HHO, is connected to the engine's air intake plenum or duct by a hose and HHO is mixed with the air and gasoline as it is drawn into the combustion chamber. The design is considered an ON DEMAND system, meaning that HHO fuel is produced only as is needed, having NO storage tank, and stopping when the ignition key is turned off.

Here, flow control valve is used to control the flow of mixture to engine and NRV for restricting the back supply of mixture. The mixture now goes into engine via flash back arrestor. The flash back arrestor is the main safety device used in the system. It is filled with water and act as a fire protecting equipment. If any accident occurs, it traps the fire and not allowed the fire to go back to the tank. The hydrogen and oxygen mixture burns with the petrol an increase the efficiency of the system.

Figure:02



II. RESULTS AND ANALYSIS

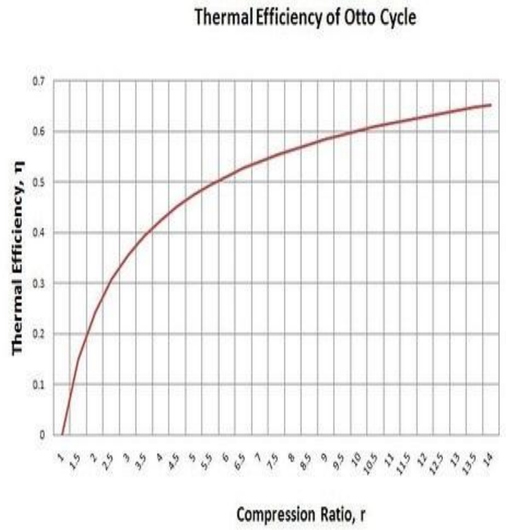
Effect of Hydrogen On 4 Stroke Engine

1.1 COMPRESSION RATIO

An experimental study on the combustion and emissions of a hydrogen-gas direct injection spark ignition engine under different compression ratios was carried out. The results show that the compression ratio has a large influence on the engine performance, combustion and emissions. The penetration distance of the hydrogen-gas jet is decreased and relatively strong mixture stratification is formed as the compression ratio is increased, The maximum cylinder gas pressure is increased with increase in the compression ratio. The exhaust hydrocarbon (HC) and carbon monoxide emissions decreased with increase in the compression ratio. This indicates that the compression ratio has a significant influence on the combustion duration at lean combustion while the exhaust nitrogen oxide emission is increased with increase in the compression ratio. The exhaust HC emission tends to increase at high compression ratios. Experiments showed that a compression ratio of 12 is a reasonable value for a compressed-natural-gas direct-injection engine to obtain a better thermal efficiency without a large penalty of emissions.

2.1 EFFICIENCY

Figure:03



It giving a fast burning rate and a high thermal efficiency, especially at low and medium engine loads. However, the brake thermal efficiency is increased with a compression ratio up to a limit of 12 at high engine loads. The flame development duration is decreased with increase in the compression ratio and this behaviour becomes more obvious with increase in the compression ratio at low loads or for lean mixture combustion

3.1 Air Fuel Ratio

The acquired results show that the air-fuel ratio is greatly influence on the performance of hydrogen fueled engine. It is shown that the brake mean effective pressure (BMEP) and brake thermal efficiency decreases with increases of the air fuel ratio however the brake specific fuel consumption (BSFC)increases with increases of the air-fuel ratio. The cylinder temperature decreases with the increase of air-fuel ratio. The present model emphasizes the ability of retrofitting the traditional engines with hydrogen fuel with minor modifications.

Fuel used in 4-Stroke IC Engine

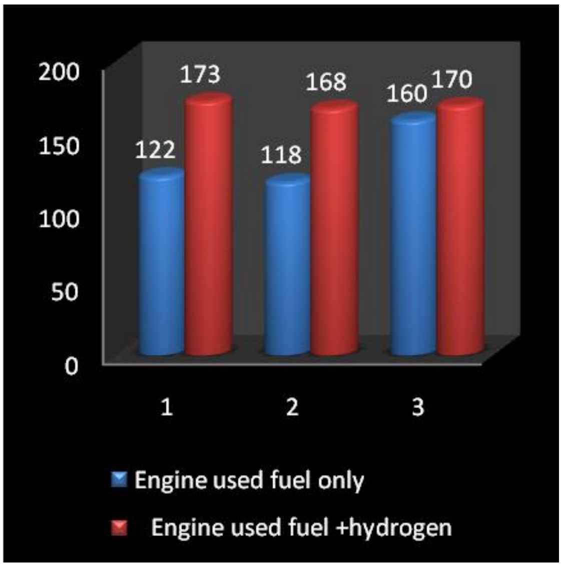
Table No:01 Engine used fuel only

Sr. No	Fuel Used In Engine (ml)	Time For Running (in sec)
1	5	122
2	5	118
3	5	160

Table No:02 Engine used fuel +hydrogen

Sr. No	Fuel Used In Engine (ml)	Time For Running (in sec)
1	5	173
2	5	168
3	5	170

Figure:04



It is worthy to mention that one of the most attractive combustive features for hydrogen fuel is its wide range of flammability. A lean mixture is one in which the amount of fuel is less than stoichiometric mixture. This leads to fairly easy to get an engine start. Furthermore, the combustion reaction will be more complete. Additionally, the final combustion temperature is lower reducing the amount of pollutants.

The effect of air-fuel ration on the brake mean effective pressure. The air-fuel ratio AFR was varied from stoichiometric limit (AFR = 34.33:1 based on mass where the equivalence ratio, =1) to a very lean limit (AFR =171.65 based on =0.2) and engine speed varied from 2500 rpm to 4500 rpm. BMEP is a good parameter for comparing engines with regard to design due to its independent on the engine size and speed. If torque used for engine comparison, a large engine was always seem to be better when considering the torque, however, speeds become very important when considered the power. It can be seen that the decreases of the BMEP with increases of AFR and speed. It is obvious that the BMEP falls with a non-linear behavior from the richest condition where AFR is 34.33 to the leanest condition where the AFR is 171.65. The differences of BMEP are increases with the increases of speed and AFR. The differences of the BMEP are decreases 6.682 bar at speed of 4500 rpm while6.12 bar at speed 2500 rpm for the same range of AFR. This implied that at lean operating conditions, the engine gives the maximum power (BMEP = 1.275 bar) at lower speed 2500

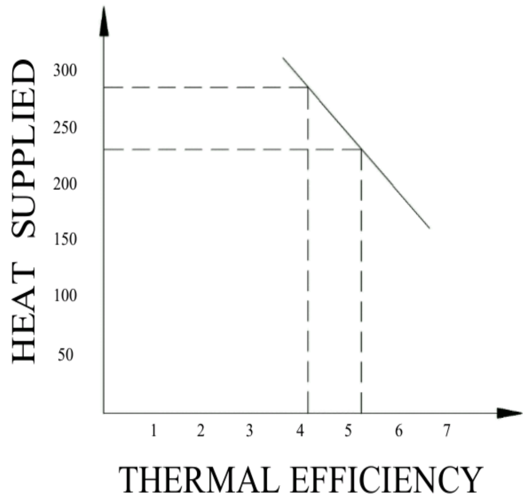
III.CONCLUSION

A conventional 4 cylinder SI engine was adapted to operate on gaseous hydrogen. Compressed gas at 200 bar in steel bottles was introduced to the engine by external mixing. The first stage regulator drops the pressure to 3 bar to a copper gas supply line where a flow meter 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 10° before TDC and fixed.

Combustion properties of hydrogen favor fast burning conditions such as in a high speed engine. Design changes that would allow the engine to greater speeds would have a beneficial effect. Appropriate changes in the combustion chamber together with better cooling of the valve mechanism, would increase the possibility of using hydrogen across a wider operating range.

At very lean conditions with low engine speeds, acceptable BMEP can be reached, while it is unacceptable for higher speeds. Lean operation leads to small values of BMEP compared with rich.

Figure:05



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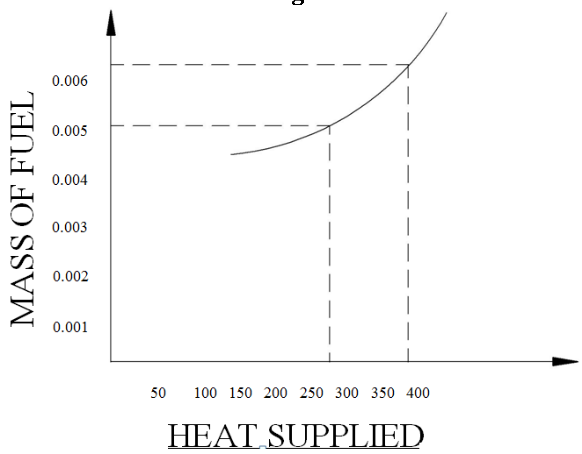
Maximum brake thermal efficiency can be reached at mixture composition in the range of (0.7 to 0.8) and it decreases dramatically at leaner conditions.

The desired minimum BSFC occurs within a mixture composition range of (0.7 to 0.9). The operation with very lean condition (< 0.2) and high engine speeds (> 4500) consumes unacceptable amounts of fuel.

Lean operation conditions results in lower maximum cylinder temperature. A reduction of around 1400 K can be gained if the engine works properly at (=0.2) instead of stoichiometric operation.

Figure:06



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