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USE OF HYDOGEN IN IC ENGINES

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ABSTRACT:

This paper describes the use of hydrogen with in IC engines to substitute the fossil fuels in order to attain energy sustainability and stepping to the way of green technology. The main purpose of presenting this paper is to explain the use of hydrogen gas as a fuel which can substitute the place of convenient fuels and to suggest the thoughts on hydrogen as a fuel in automobile engineering. Thus, Hydrogen is one of two natural elements that combine to make water. Hydrogen is not an energy source, but an energy carrier because it takes a great deal of energy to extract it from water.

Keywords: Hydrogen, Fuels, Combustion, Engine, Explosion, Conventional fuels.

I. INTRODUCTION

Hydrogen is a forever fuel that can never run out. It is the simplest element in the universe which occurs naturally as a gas. It is a viable alternative fuel which can be used in many applications on account of its various advantages. One such application is the use of hydrogen with in IC engine. The properties that contribute to its use as a combustible fuel are its:-

- Wide range of flammability
- Low ignition energy
- Small quenching distance
- High auto ignition temperature
- High flame speed at stoichiometric ratios
- High diffusivity
- Very low density.

II. HISTORY

Francois Isaac de Rivaz designed in 1806 the De Rivaz engine, the first internal combustion engine, which ran on a hydrogen/oxygen mixture. Étienne Lenoir produced the Hippomobile in 1863. Paul Dieges patented in 1970 a modification to internal combustion engines which allowed a gasoline powered engine to run on hydrogen. Mazda has developed Wankel engines that burn hydrogen. Existing-technology ICE can still be used to solve those problems where fuel cells are not a viable solution as yet, for example in cold-weather applications. Recently, BMW tested a supercar named the BMW Hydrogen 7, powered by a hydrogen ICE, which achieved 301 km/h (187 mph) in tests. At least two of these concepts have been manufactured.

Figure1: Hydrogen Powered 1965 Cobra Replica.

III. METHODS OF PRODUCTION OF HYDROGEN

3.1 Steam reforming of methane

- **Reformation of natural gas:**

  The first step of the SMR process involves methane reacting with steam at 750-800 ^{O}C (1380-1470 F) to produce a synthesis gas (syngas), a mixture primarily made up of hydrogen and carbon monoxide (CO)

- **Shift reaction:**

  In the second step, known as a water gas shift (WGS) reaction, the carbon monoxide produced in the first reaction is reacted with steam over a catalyst to form hydrogen and carbon dioxide. This process occurs in two stages, consisting of a high temperature shift (HTS) at 350 ^{O}C (662 F) and a low temperature shift (LTS) at 190-210 ^{O}C (374-410F)

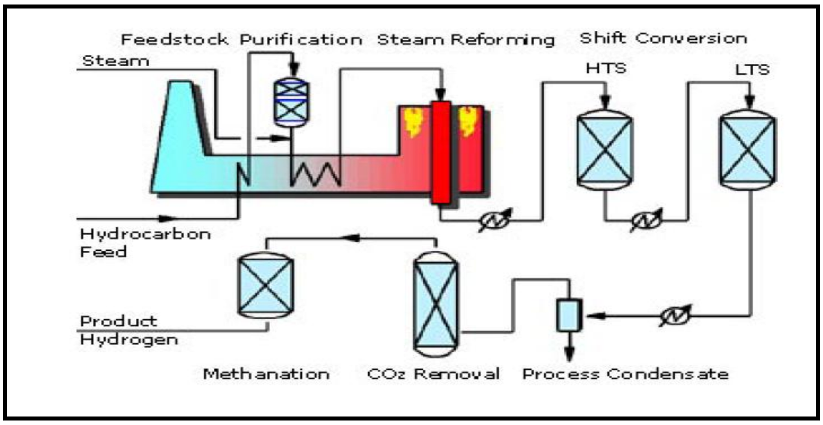

Figure 2: Steams Reforming Of Methane

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3.2 Production of hydrogen by water electrolysis

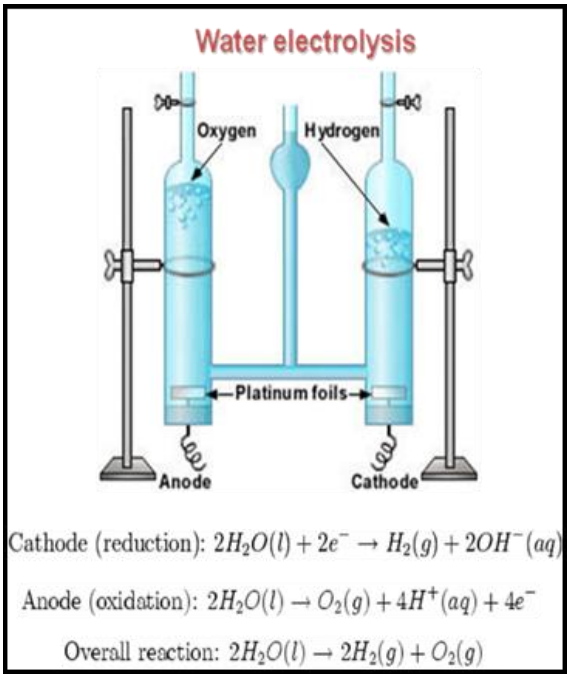

Figure 3: Production of hydrogen by water electrolysis

IV. AIR-FUEL RATIO

The correct A/F ratio for the complete combustion of hydrogen in air is about 34:1 by mass. This means that for complete combustion, 34 pounds of air are required for every pound of hydrogen. This is much higher than the 14.7:1 A/F ratio required for gasoline. Because of hydrogen's wide range of flammability, hydrogen engines can run on A/F ratios of anywhere from 34:1 to 180:1.

V. COMBUSTION OF HYDROGEN

Since hydrogen is a gaseous fuel at ambient conditions it displaces more of the combustion chamber than a liquid fuel. Consequently less of the combustion chamber can be occupied by air. At stoichiometric conditions, hydrogen dis- places about 30% of the combustion chamber, compared to about 1 to 2% for gasoline. Figure 3 compares combustion chamber volumes and energy content for gasoline and hydrogen fueled engines. Depending the method used to meter the hydrogen to the engine, the power output compared to a gasoline engine can be anywhere from 85% (intake manifold injection) to 120% (high pressure injection). Because of hydrogen's wide range of flammability, hydrogen engines can run on A/F ratios of anywhere from 34:1 (stoichiometric) to 180:1. The A/F ratio can also be ex-pressed in terms of equivalence ratio, denoted by phi (Φ). Phi is equal to the stoichiometric A/F ratio divided by the actual A/F ratio. For a stoichiometric mixture, the actual A/F ratio is equal to the stoichiometric A/F ratio and thus the phi equals unity (one). For lean A/F ratios, phi will be a value less than one. For example, a phi of 0.5 means that there is only enough fuel available in the mixture to oxidize with half of the air available. Another way of saying this is that there is twice as much air available for combustion than is theoretically required.

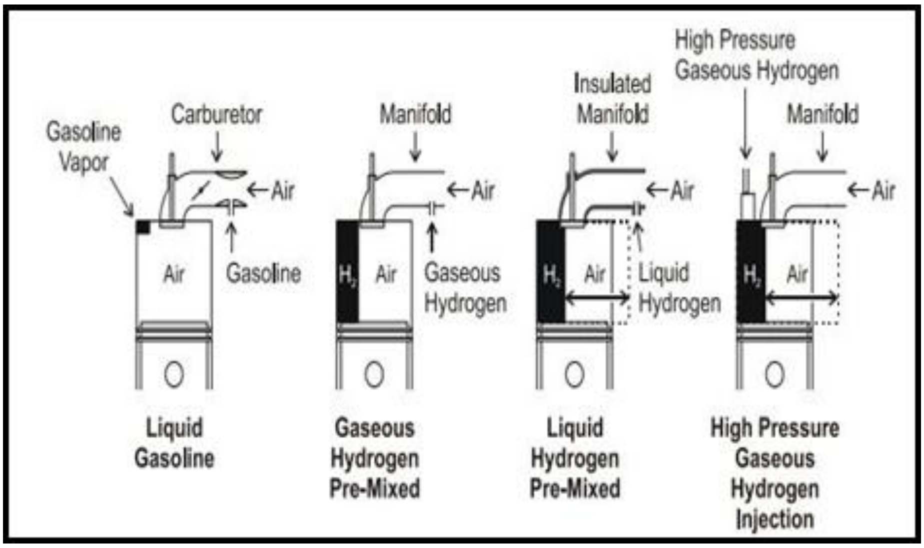

Figure 4: Combustion Chamber Volumetric and Energy Comparison for Gasoline and Hydrogen Fueled Engines.

VI. ENGINE DESIG

The most effective means of controlling pre-ignition and knock is to re-design the engine for hydrogen use, specifically the combustion chamber and the cooling system. A disk-shaped combustion chamber (with a flat piston and chamber ceiling) can be used to reduce turbulence within the chamber. The disk shape helps produce low radial and tangential velocity components and does not amplify inlet swirl during compression. Since unburned hydrocarbons are not a concern in hydrogen engines, a large bore-to-stroke ratio can be used with this engine. To accommodate the wider range of flame speeds that occur over a greater range of equivalence ratios, two spark plugs are needed. The cooling system must be de- signed to provide uniform flow to all locations that need cooling.

Figure 6: Pressure Relief Valve on Engine Crankcase

Crankcase ventilation is even more important for hydrogen engines than for gasoline engines. As with gasoline engines, unburnt fuel can seep by the piston rings and enter the crankcase. Since hydrogen has a lower energy ignition limit than gasoline, any unburnt hydrogen entering the crankcase has a greater chance of igniting. Hydrogen should be prevented from accumulating through ventilation. Ignition within the crankcase can be just a startling noise or result in engine fire. When hydrogen ignites within the crankcase, a sudden pressure rise occurs. To relieve this pressure, a pressure relief valve must be installed on the valve cover. A typical pressure relief valve installation is shown in Figure. Exhaust gases can also seep by the piston rings into the crankcase. Since hydrogen exhaust is water vapor, water can condense in the crankcase when proper ventilation is not provided. The mixing of water into the crankcase oil reduces its lubrication ability, resulting in a higher degree of engine wear.

VII. THERMAL EFFICIENCY

The theoretical thermodynamic efficiency of an Otto cycle engine is based on the compression ratio of the engine and the specific-heat ratio of the fuel as shown in the equation:

$$\eta_{th} = 1 - \frac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}}$$

Where:

V1/V2 = the compression ratio

γ = ratio of specific heats

η(th)= theoretical thermodynamic efficiency.

The higher the compression ratio and/or the specific-heat ratio, the higher the indicated thermodynamic efficiency of the engine. The compression ratio limit of an engine is based on the fuel's resistance to knock. A lean hydrogen mixture is less susceptible to knock than conventional gasoline and therefore can tolerate higher compression ratios. The specific-heat ratio is related to the fuel's molecular structure. The less complex the molecular structure, the higher the specific-heat ratio. Hydrogen (γ = 1.4) has a much simpler molecular structure than gasoline and therefore its specific-heat ratio is higher than that of conventional gasoline (γ = 1.1).

VIII. POWER OUTPUT

The theoretical maximum power output from a hydrogen engine depends on the air/fuel ratio and fuel injection method used. As mentioned in Section 3.3, the stoichiometric air/fuel ratio for hydrogen is 34:1. At this air/fuel ratio, hydrogen will displace 29% of the combustion chamber leaving only 71% for the air. As a result, the energy content of this mixture will be less than it would be if the fuel were gasoline (since gasoline is a liquid, it only occupies a very small volume of the combustion chamber, and thus allows more air to enter).

Since both the carbureted and port injection methods mix the fuel and air prior to it entering the combustion chamber, these systems limit the maximum theoretical power obtain-able to approximately 85% of that of gasoline engines. For direct injection systems, which mix the fuel with the air after the intake valve has closed (and thus the combustion chamber has 100% air), the maximum output of the engine can be approximately 15% higher than that for gasoline engines. Therefore, depending on how the fuel is metered, the maxi-mum output for a hydrogen engine can be either 15% higher or 15% less than that of gasoline if a stoichiometric air/fuel ratio is used. However, at a stoichiometric air/fuel ratio, the combustion temperature is very high and as a result it will form a large amount of nitrogen oxides (NOx), which is a criteria pollutant. Since one of the reasons for using hydrogen is low exhaust emissions, hydrogen engines are not normally designed to run at a stoichiometric air/fuel ratio. Typically hydrogen engines are designed to use about twice as much air as theoretically required for complete combustion. At this air/fuel ratio, the formation of NOx is reduced to near zero. Unfortunately, this also reduces the power out-put to about half that of a similarly sized gasoline engine. To make up for the power loss, hydrogen engines are usually larger than gasoline engines, and/or are equipped with turbochargers or superchargers.

IX. ADVANTAGES

- Created from water, can be recycled to produce more hydrogen.
- High calorific value about 1, 41,000 KJ/Kg.
- Cleanest fuel available when combusted – produces carbon monoxide, carbon dioxide, or hydrocarbon emissions.
- As it produces high energy it reduces the quantity of other fuel required considerably.
- Domestic production will allow for energy independence.
- Provides more energy than any conventional fuel.
- Can be refined from any substance that contains hydrogen.
- Betterment of health, environment, economy, and energy security.
- Increases efficiency of the system.

X. IMITATIONS

- For instance, you don't have a hydrogen pipeline coming to your house, and you can't pull up to a hydrogen pump at your local gas station.
- Hydrogen is difficult to store and distribute, so it would be much more convenient if fuel cells could use fuels that are more readily available.
- Technology is currently expensive.
- There are several technical challenges to the commercialization and widespread use of hydrogen as energy.

XI. FUTURE SCOPE

- Global interest continues to grow
- Prototypes from automotive manufacturers
- Infrastructure and vehicle developments still required
- There is a lot of advancement been done by the R and D sectors

XII. CONCLUSION

Thus, we can conclude that Hydrogen holds the potential to provide clean, safe, affordable, and secure energy from abundant domestic resources. It's a green and eco-friendly technology which can be used efficiently. The great promise of hydrogen to provide clean, safe, reliable, and abundant energy has prompted both government and industry to make significant investments in research, development, and demonstration activities needed to bring hydrogen and fuel cell technologies to the commercial market.

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