USE OF HYDROGEN IN INTERNAL COMBUSTION

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Abstract: Are based differences that occur in automotive when you wish to use hydrogen as non-polluting fuel, instead of hydrocarbon fuels.
Key words: Flammability, Low Ignition Energy, Air-Fuel Ratio.

1. INTRODUCTION

The earliest attempts at developing a car powered by hydrogen belonging to English: reverend W. Cecil, in 1820.

He presented the discovery entitled "On the Application of Hydrogen Gas to Produce Moving Power in Machinery" before the Cambridge Philosophical Society.

The engine itself operated on the vacuum principle, in which atmospheric pressure drives a piston back against a vacuum to produce power.

The vacuum is creating by burning a hydrogen-air mixture, allowing it to expand and then cool.

Although the engine was going well, has never been considered by engineers of that period.

Between 1860 and 1870, N.A. Otto (Otto cycle inventor) reported use of the gas-based hydrocarbons, which probably contained 50% hydrogen.

He tried to work with gasoline, but considering it too dangerous to quit and returned to gaseous fuels.

In addition to the traditional use of hydrogen, it is now the only form of fuel used in the space program. In recent years, in the light of drastic climate change, appeared need to reduce dependence on fossil fuels and hydrogen occupies first place on the list fuel future.

2.COMBUSTIVE PROPERTIES OF HYDROGEN

-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

Wide Range of Flammability

Hydrogen has a wide flammability range in comparison with all other fuels.

As a result, hydrogen can be combusted in an internal combustion engine over a wide range of fuel-air mixtures.

A significant advantage of this is that hydrogen can run on a lean mixture.

A lean mixture is one in which the amount of fuel is less than the theoretical, stoichiometric or chemically ideal amount needed for combustion with a given amount of air.

This is why it is fairly easy to get an engine to start on hydrogen.

Generally, fuel economy is greater and the combustion reaction is more complete when a vehicle is run on a lean mixture.

Additionally, the final combustion temperature is generally lower, reducing the amount of pollutants, such as nitrogen oxides, emitted in the exhaust. There is a limit to how lean the engine can be run, as lean operation can significantly reduce the power output due to a reduction in the volumetric heating value of the air-fuel mixture.

Low Ignition Energy

Hydrogen has very low ignition energy.

The amount of energy needed to ignite hydrogen is about one order of magnitude less than required for gasoline.

This enables hydrogen engines to ignite lean mixtures and ensures prompt ignition.

Unfortunately, the low ignition energy means that hot gases and hot spots on the cylinder can serve as sources of ignition, creating problems of premature ignition and flashback.

Preventing this is one of the challenges associated with running an engine on hydrogen.

The wide range flammability of hydrogen means that almost any mixture can be ignited by a hot spot.

Small Quenching Distance

Hydrogen has a small quenching distance, smaller than gasoline. Consequently, hydrogen flame travels closer to the cylinder wall than other fuels before they extinguish. Thus, it is more difficult to quench a hydrogen flame than a gasoline flame.

The smaller quenching distance can also increase the tendency for backfire since the flame from a hydrogen-air mixture more readily passes a nearly closed intake valve, than a hydrocarbon-air flame.

High Auto Ignition Temperature

Hydrogen has a relatively high auto ignition temperature.

This has important implications when a hydrogen-air mixture is compressed.

In fact, the auto ignition temperature is an important factor in determining what compression ratio an engine can use, since the temperature rise during compression is related to the compression ratio.

The temperature rise is shown by the equation:

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

Where:

$\frac{V_1}{V_2}$ - The compression ratio;

T_1 - Absolute initial temperature;

T_2 - Absolute final temperature;

γ - Ratio of specific heats;

The temperature may not exceed hydrogen's auto ignition temperature without causing premature ignition.

Thus, the absolute final temperature limits the compression ratio.

The high auto ignition temperature oh hydrogen allows larger compression ratios to be used in a hydrogen engine than in a hydrocarbon engine.

On the other hand, hydrogen is difficult to ignite in a compression ignition or diesel configuration, because the temperature needed for those types of ignition are relatively high.

High Flame Speed

Hydrogen has high flame speed at stoichiometric ratios. Under these conditions, the hydrogen flame speed is nearly an order of magnitude higher (faster) than that of gasoline. This means that hydrogen engines can more closely approach the thermodynamically ideal engine cycle.

At leaner mixtures, however, the flame velocity decreases significantly.

High Diffusivity

Hydrogen has very high diffusivity. This ability to disperse in air is considerably greater than gasoline and is advantageous for two main reasons.

Firstly it facilitates the formation of a uniform mixture of fuel and air. Secondly, if a hydrogen leak develops, the hydrogen disperses rapidly.

Thus, unsafe conditions can either be avoided or minimized**.**

Very Low Density

Hydrogen has very low density. This results in two problems when used in an internal combustion engine.

Firstly, a very large volume is necessary to store enough hydrogen to give a vehicle an adequate driving range.

Secondly, the energy density of a hydrogen air mixture, and hence the power output, is reduced.

Air-Fuel Ratio

The theoretical or stoichiometric combustion of hydrogen and oxygen is given as:

$$2H_2 + O_2 = 2H_2O$$

Hence, for a complete combustion: 2moles of hydrogen and 1mole of oxygen.

Because air is used as the oxidizer instead oxygen, the nitrogen in the air needs to be included in the calculation:

Moles of N_2 in air = moles of O_2 x (79% N_2 in air / 21% O_2 in air) =

= 1 mole of O_2 x (79% N_2 in air / 21% O_2 in air) = **3.762 moles N_2**

Number of moles of air = moles of O_2 + moles of N_2 = 1 + 3.762 = **4.762 moles of air.**

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

Weight of N_2 = 3.762 moles of N_2 x 28 g/mole = **105.33 g**

Weight of air = weight of O_2 + weight of N_2 = 32g + 105.33g = **137.33g**

Weight of H_2 = 2 moles of H_2 x 2g/mole = **4g**

Stoichiometric air/fuel (A/F) ratio for hydrogen and air is:

A/F based on mass = mass of air / mass of fuel 137.33g / 4g = **34.33: 1**

A/F based on volume = volume (moles) of air / volume (moles) of fuel =

= 4.762 / 2 = **2.4: 1**

The percent of combustion chamber occupied by hydrogen for a stoichiometric mixture (%H_2) = volume (moles) of H_2/total volume =

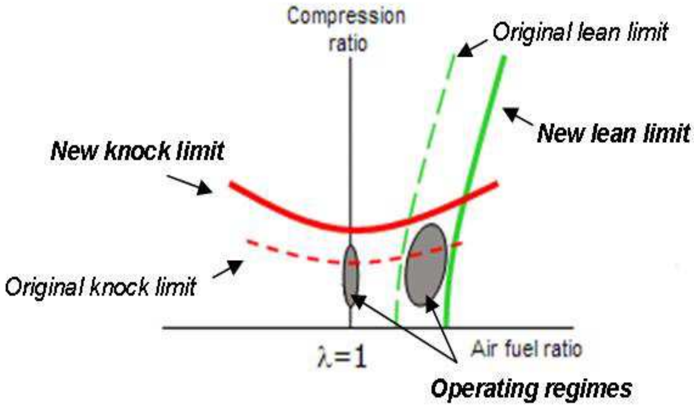
= volume H_2/ (volume air + volume H_2) = 2/ (4.762+2) ≡ **29.6%**

As these calculations show, the stoichiometric A/F ratio for the complete combustion of hydrogen in air is about 34: 1 by mass.

This means that for complete combustion, 34 grams of air are required for every gram of hydrogen. This is much higher than the 14.7: 1 A/F ratio requires for gasoline.

Since hydrogen is a gaseous fuel at ambient conditions, it displaces more of the combustion chamber can be occupied by air.

At stochiometric conditions, hydrogen displaces about 30% of the combustion chamber, compared to about 1 to 2% for gasoline.



- This article found that hydrogen can become the future non-polluting fuel, but does not answer at the most important question: **which are the costs for its production?**
- A second option is to enrich the air drawn into the engine with a small amount of hydrogen and oxygen from the electrolysis of a water plant.

  Experimental findings show that a water electrolysis plant, which consumes about 100W (max. 9A / 12V) releases enough hydrogen and oxygen to provide a fuel consumption reduction of 20% - 30%.

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