Comparative Study and Data Analysis of Combustive Properties of Hydrogen Fuel and Other Conventional Fuels

Vishal Kumar Mittal
Gulzar College of Engineering, Khanna
Punjab, India

Nirbhai Singh
Gulzar College of Engineering, Khanna
Punjab, India

***Abstract*—This paper discusses the environmental issues arise due to the combustion of fossil fuels to get energy for vehicles and compares the various combustive properties of these fuels with the Hydrogen. The industrialization and commercialization plans in the world have improved the living standards but the environment gets depleted. This paper also presents the role of Hydrogen to improve the degrading environmental conditions. The most important need is energy, therefore the process through which this energy is get extracted from the fuel is as much a subject of concern as the energy contained in the fuel. This paper shows how the hydrogen is a better energy carrier and opens the door for sustainable development.**

Key Words — Hydrogen Fuel; Fossil Fuels; Combustive Properties; Carbon Emission; Sustainable Development;

I. INTRODUCTION

The increasing pollution is the major concern of today's world. The transportation is one of the major sector contributing in the pollution. Our transportation sector is heavily dependent on the fossil fuels, the combustion of these fossil fuels to meet our energy demand has declined the quality of air. Carbon dioxide, carbon monoxide, oxides of nitrogen and the particulate matter are the major pollutants which are emitted from the vehicles. The carbon dioxide has contributed to the global warming and the particulate matter ($PM_{2.5}$ and PM_{10}) which remain in air for days and weeks have possessed the bad effects on health and the environment. These fine particles reach to the lungs and cause chronic respiratory diseases such as asthma etc. and on the other hand these fine particles remain for days in air, carried by air to the lakes, rivers etc. making them acidic and also depleting the soil quality. On 21 April, 2016 in Delhi the index value of $PM_{2.5}$ and PM_{10} was 270 which is poor and that of Gurgaon, India was 312 which is very poor. A report suggested that air pollution in India is estimated to kill 1.5 million people every year[1]. According to WHO, India has the world's largest death rate from chronic respiratory diseases and asthma. The oxides of nitrogen has contributed to the tropospheric ozone and increasing temperature is helping in its production. The bad effects on health caused due to the tropospheric ozone are effects on respiratory system causing coughing, throat irritation and uncomfortable sensation in the chest. Reduction in the functioning of lungs, making it more difficult to breathe deeply and vigorously. Ozone makes people more sensitive to allergens, therefore risk of asthma attacks increases. It also causes inflammation and damage to the lining of the lungs.

It also affects plants by slowing down the process of photosynthesis and plant growth as higher concentration of ozone causes the stomata to close down which open to allow carbon dioxide to diffuse in and water to diffuse out, a part of photosynthesis. As ozone is a highly oxidizing gas therefore it directly damages the internal cells of plants.

II. DESCRIPTION

A. Enthalpy of Combustion: Enthalpy of combustion is the amount of energy released during the combustion of 1kg of fuel. It is the measurement of energy to weight ratio. Greater the enthalpy of combustion, better the fuel is.

B. Auto-ignition Temperature: Auto-ignition temperature of a fuel is the lowest temperature at which the fuel gets spontaneously ignited without the presence of a flame or spark. The auto-ignition temperature of fuel tells about how much the fuel is safe. It should be higher than the required temperature of the site, otherwise the fuel gets exploded by itself and become a hazard.

C. Flammability range: Flammability range is the range of concentration of fuel in air that is capable of producing flash of fire in presence of an ignition source. This range lies between the lower flammability range and the upper flammability range.

Lower flammability range is the lowest concentration of gas or vapour in air that is capable of producing a flash in the presence of an ignition source (arc, flame or heat). The concentration of gas in air lower than this will not ignite the mixture. Similarly, the highest concentration of gas or vapour in air that is capable of producing flash in presence of an ignition source is called the upper flammability range. The concentration of gas in air higher than this is too rich to burn. The range between these two limits describe the flammability range of the fuel. This range should be high such that the fuel can be burnt with various fuel to air ratios.

*D. **Minimum Ignition Energy**:* Minimum ignition energy (MIE) is the minimum amount of energy required to ignite a combustible vapour, gas or dust cloud. This energy should be low such that lesser amount of energy will get consumed during the ignition of the fuel.

E.. Diffusivity: Diffusivity of the gaseous fuel is the property by which the fuel gets diffused in air. The greater the diffusivity, lesser the fuel is hazardous. If somehow the fuel gets leaked, due to its diffusive property it gets diffused in air minimizing the fire hazard. Higher the diffusive property more rapidly the fuel gets diffused in air.

F. Flame Speed: The flame speed is the measured rate of expansion of the flame front in a combustion reaction. Higher the flame speed, more closure the engine towards ideal one. With this the efficiency of the engine increases. The unburnt fuel also depends upon flame speed, thus greater the flame speed, the emission of unburnt fuel reduces

G. Combustion products: Combustion is the process of burning of fuel in air. If the products yield during this chemical reaction are non-pollutants, the fuel is said to be clean fuel.

III. RESULT

A. *Enthalpy of Combustion :*

The Fig. 1 describes the enthalpy of combustion of various fuels. The graph depicts that the enthalpy of combustion of hydrogen is around 142 MJ/kg[2] where as that of petrol is around 48 MJ/kg[2], which is around three times that of petrol.

Therefore, the energy to weight ratio of hydrogen is very good i.e. lesser amount of hydrogen will be needed to produce the same amount of energy than the other mentioned fuels.

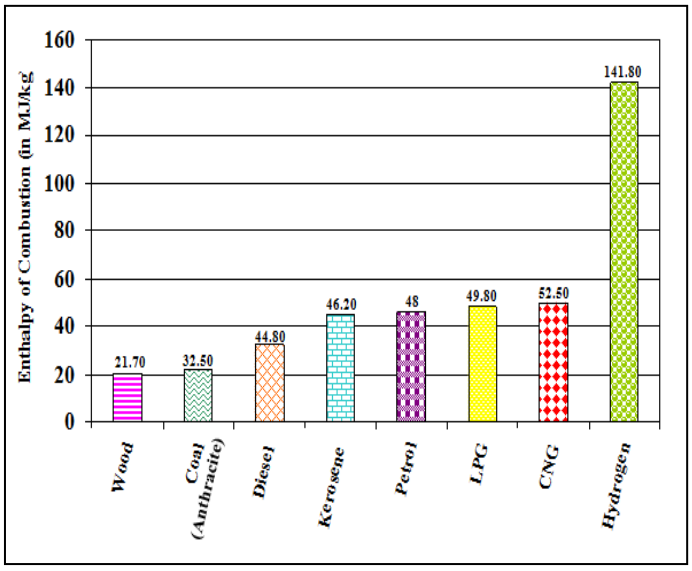

Fig. 1. Enthalpy of Combustion of different fuels

B. *Auto-ignition Temperature :*

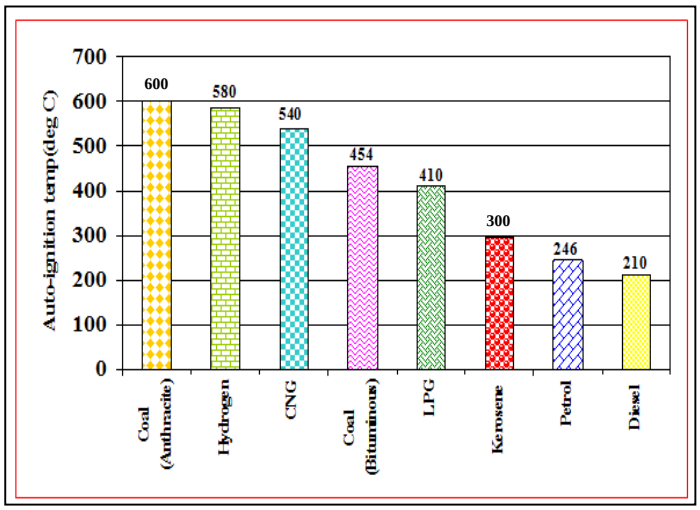

Fig. 2. Auto-ignition Temperature of various fuels

From Fig. 2, we can see that the auto-ignition temperature of hydrogen is around 580^{0}C which is very much higher than diesel, petrol and kerosene. Therefore, hydrogen is much safer fuel.

B. *Flammability range :*

Fig. 3 describes the flammability range of various fuels. As from the graph, hydrogen has maximum flammability range. The vehicle running on hydrogen IC engine can be supplied with various hydrogen to air by volume ratio.

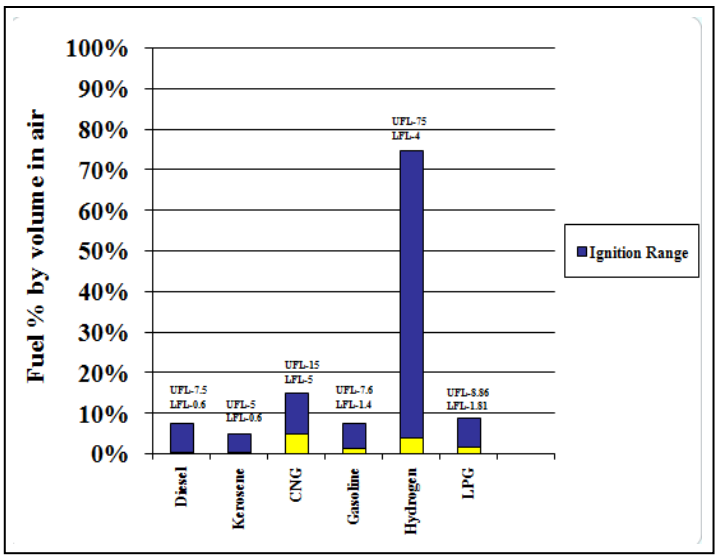

Fig. 3. Flammability range of different fuels

C. Minimum Ignition Energy :

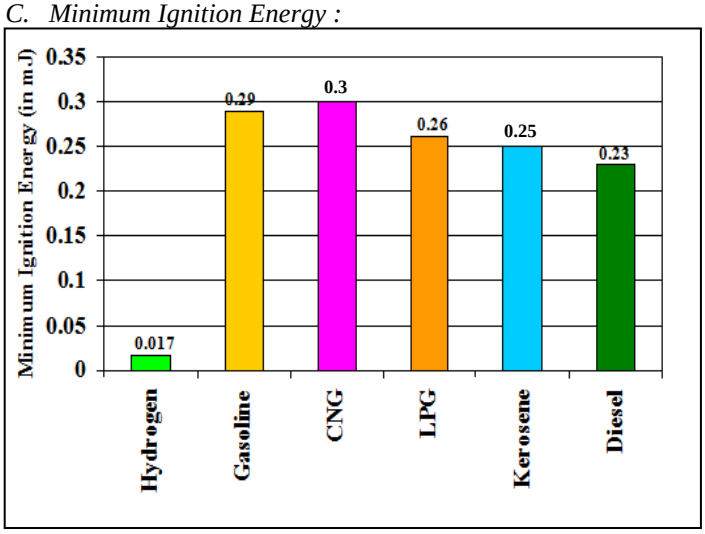

Fig. 4. Minimum Ignition Energy requirement of different fuels

As from Fig. 4, the hydrogen has least minimum ignition energy i.e. 0.017 mJ. Therefore, hydrogen can be ignited easily by giving very low energy.

E. Diffusivity:

Hydrogen has very high diffusivity. The diffusivity of hydrogen is considerably higher than the gasoline. Thus hydrogen favours uniform combustion, hence better efficiency. Also due to its higher diffusivity the possibility of fire hazards due to the leakage of gas are minimum as hydrogen gets dispersed in air quickly.

F. Flame Speed :

It is seen from Fig. 5 that hydrogen has high flame speed, around 2.83 m/s. Thus, engine running on hydrogen fuel has better efficiency than other fuels.

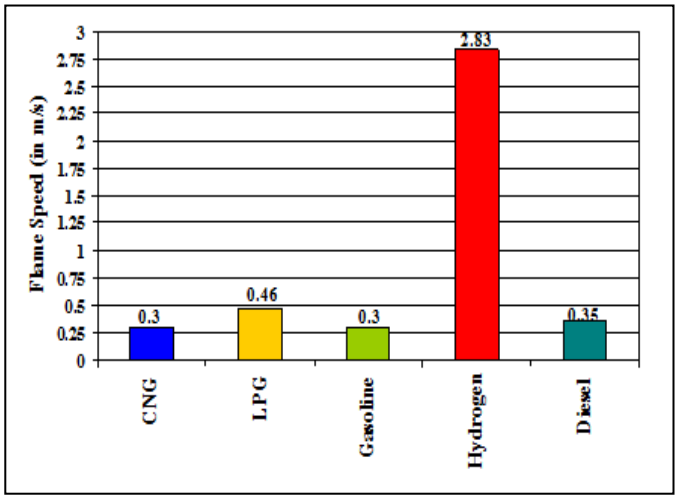

Fig. 5. Flame Speed of different fuels

G. Combustion Products:

When Petrol, Diesel, LPG, CNG etc. are combusted in engine there is emission of Carbon dioxide (CO_2) and other air pollutants like oxides of nitrogen, oxides of sulphur, carbon monoxide and particulate matter. This is because these fuels have carbon in their composition. When hydrogen is combusted, the product is water.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

As from the above chemical equation, there is no emission of pollutant, hence hydrogen is a clean fuel.

IV. CONCLUSION

In today's time, transportation is one of the vital need so we cannot reduce it, we require a clean fuel in place of fossil fuels. One such fuel is hydrogen. Hydrogen has excellent combustive properties. The hydrogen has ability to take the place of fossil fuels, moreover it is far better than other fuels. The more important property is that there is no emission of carbon and other pollutants. Carbon dioxide is mainly responsible for the global warming and the increasing temperature supports the tropospheric ozone production, as there is no emission of these pollutants from the combustion of the hydrogen fuel, a healthy environment can be created.

V. FUTURE SCOPE

Hydrogen is produced through steam reforming[3] process but it is not a clean process. There are also clean methods for the production of hydrogen, such as solar hydrogen production[4], photoelectrochemical process of hydrogen production[5] in which the water is photoelectrochemically splitted into hydrogen gas.

Hydrogen has low energy to volume ratio but high energy to weight ratio. There are methods to reduce the storage and transportation problems of hydrogen such as metal hydride storage technique[6] and carbon adsorption technique[7] which are very much safer techniques of storing hydrogen. The amount of hydrogen stored in vessel filled with the metal hydride can be 2-3 times larger than that in the same vessel filled with the liquid hydrogen. These vessels could be used in vehicles instead of cylinders containing hydrogen gas at high pressure.

ACKNOWLEDGMENT

We would like to extend our gratitude first and foremost to Dr. Arvind Dhingra for his guidance and availing NCERT lab of Guru Nanak Dev Engineering College, Ludhiana, Punjab to carry out research.

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