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Hydrogen as an additive in Internal Combustion Engines a Review

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Abstract - **Due to the increase in dependency in non-renewable energy resources, there has been studies and interest in using a cleaner and more eco-friendly approach to consuming energy. One of the methods in obtaining clean energy is the utilization of hydrogen. Hydrogen is an abundant element on Earth and stands out from the rest of the renewable forms of energy. Hydrogen is the fuel of the future. Hydrogen is an energy carrier that can be used in internal combustion engines or fuel cells producing virtually no greenhouse gas emissions when combusted with oxygen. The only significant emission is water vapor. Hydrogen production and storage is currently undergoing extensive research. Hydrogen can be used as the primary fuel in an internal combustion engine or in a fuel cell. A hydrogen internal combustion engine is similar to that of a gasoline engine, where hydrogen combusts with oxygen in the air and produces expanding hot gases that directly move the physical parts of an engine. The only emissions are water vapor and insignificant amounts of nitrous oxides.**

***Keywords* — Emission control , Fuel Cell , Gasoline engines , HHO Fuel, , Hydrogen, , Hydrogen Production.**

I. INTRODUCTION

Hydrogen is a renewable and is the abundant resource easily available on planet earth. The ability of hydrogen to be blended to various fuels makes it burn more effectively due to its low ignition, the high diffusivity, energy high flame speed and wide flammability limits [9]. The properties of hydrogen in better in comparison to hydrocarbon fuels are given in Table-1.

When hydrogen is used as additive fuel, because of its high diffusivity it combines with the fuel and air mixture, and form a highly uniform combustible mixture. Wide flammability of hydrogen allows a leaner mixture which can be burn in engine[1], Hence leaner mixture will reduce fuel consumption.

However the challenges in using hydrogen as a fuel additive is the high cost of hydrogen gas production and storage and the danger involved in carrying compressed hydrogen gas and increase emission of nitrogen oxides (NOx).

Properties	Hydrogen	Gasoline	Diesel
Minimum ignition energy (mJ)	0.02	0.24	NA
Flammability limits (volume % in air)	4-75	1.4-7.	0.7-5
Stoichiometric air fuel ratio (by mass)	34.3	14.6	14.5
Net heating value (MJ/Kg	120	44	42.5
Octane number	130	92-98	30
Autoignition Temperature (K)	858	533-733	530

TABLE 1

II. REVIEW OF LITERATURE

B. V Chauhan et al. (2015).In this experiment also concluded that total fuel gas includes higher net heating value and diffusivity of consumption, specific fuel consumption, un burnt hydrogen in air when compared to fossil fuels. Emissions of hydrocarbon emission, carbon monoxide, oxides of nitrogen complete combustion can result in the reduction of emission for brown's gas enriched operation at exhaust emissions such as hydrocarbons (HCs), nitrogen full load gives 6%, 11%, 88%, 94%, 58% and 18% lesser oxides (NOx) and carbon monoxide (CO). High diffusivity of hydrogen produces a much faster flame velocity that can lead to a better acceleration and torque output from the engine[2].

The hydrogen explosion is rapid and it takes volume in the combustion cylinder at three times faster than the gasoline detonation and ignites the fuel from all directions, instead of the spark in one end of the combustion cylinder, and fuel burns in a short time. In This work developed a hydroxyl

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gas produce unit that can be used with petrol engines to reduce petrol consumption. These substitute the petrol up to 20% and increase the engine thermal efficiency and also reduce the fuel consumption.[3].

S. Jadhav et al.(2015)[1] The experiment was conducted on 256cc S.I. engine using carburettor system. The engine was coupled to electrical dynamometer in order to load the engine. For loading engine four electrical heaters each of 350 watts available in the system. The gasoline fuel consumption was measured by fuel burette and stop watch and Air box method was used for measured consumption of air. HHO production system was integrated with engine setup. HHO gas generated by dry cell using 12 volt external DC supply. The work was carried out on 250cc single cylinder petrol engine under constant speed with varying load condition and amount of HHO gas aspirated into the combustion chamber along with intake air system at three different amperes i.e. 1 ampere, 2 ampere and 3 ampere with 12 volts DC supply The result shows that at full load, fuel consumption is reduced about 18.87 % in HHO supplemented petrol engine than the normal petrol engine. This is because of better combustion; the uniform mixture of air especially the oxygen of original ratio makes it overall leaner mixture and HHO gas assists gasoline during combustion process and complete combustion is due to its property high flame speed and wide flammability range the engine performance was best at 3 ampere, brake thermal efficiency of the engine increased by 3.72 %, total brake specific fuel consumption reduced by 19.48%,The decrease in BSFC is due to high energy content of the hydrogen present in the gas mixture, and also the combustion rate is high due to faster flame speed than gasoline assists to have more complete combustion, the carbon monoxide (CO) and hydrocarbon (HC) has been reduced to about 16.47 % and 28.33 %.Engine brake thermal efficiency is improved after hydrogen enrichment. It is increased by 1.42% at 1 ampere 12v, 2.43% at 2 ampere 12v and 3.72% at 3 ampere 12v at full load condition.

B. Sudarmanta et al.(2016)[4] In this work, the engine is modified into dual fuel system gasoline-HHO gas engine. HHO gas fed into the engine through the addition of shaped venturi mixer equipment and assembly on the air intake manifold after the air filter. The addition of HHO gas can reduce the magnitude of bsfc compared to gasoline fuel. The influence of the addition of HHO gas on engine with the standard ignition timing indicates an decrease in the average bsfc Optimum performance of HHO gas generator is generated by pwm with 40% duty cycle with parameters such as specific energy input of 33 121 MJ/kg, generator efficiency of 20,064% and generator temperature can be maintained below 60°C.

M. K. Baltacioglu et al.(2016)[5] In this work four sets of experiments were carried out by them. First set of experiments was performed with neat diesel fuel, second set of experiments with B10, third set of experiments with pure hydrogen enriched B10 and fourth set of experiments was with hydroxy gas (HHO) enriched B10 fuel. Using pure hydrogen or HHO in combustion chamber can lead better thermodynamic efficiency. Hydrogen has higher heating value and flame speed compared to conventional liquid fuels. Hence, both of the hydrogen enriched fuels in this study provide better brake torque outputs than neat diesel fuel and B10. Peak points of brake torque values measured at 1400 rpm for all test fuels. Similar to the brake power outputs, maximum brake torque point of 209.57 Nm at 1400 rpm is obtained by HHO+B10 enrichment fuel. Results obtained by the hydroxy gas and hydrogen enriched fuels have provided better CO2 exhaust emissions than diesel fuel. Also HHO+B10 fuel Resulted in higher engine performance results compared to the H2+B10 and neat diesel. They found that HHo can be easily produced and is cost effective method compared to high cost of transporting and storage of hydrogen.

K. V. Shivaprasad et al.(2014)[6] They have carried out experiments on high speed single cylinder Lombardini make LGA-340 gasoline engine. The tests were carried out at engine speeds of 2000 to 4000 rpm with an increment of 500 rpm. Hydrogen energy fraction on volume basis of 5%, 10%, 15%, 20% and 25% was adjusted with the help of regulator. The compressed hydrogen at 200 bar is supplied from 50 kg steel gas tank Results found that brake thermal efficiency was 27.5% for 0% hydrogen addition, 29.4 % for 5% hydrogen addition, 30.5% for 10% hydrogen addition, 32.5% for 15% hydrogen addition, 34.2% for 20% hydrogen addition and 32.8% for 25% hydrogen addition. Considerable increase in brake thermal efficiency was found with addition of hydrogen. Also CO emission is decreases as the hydrogen gasoline blend percentage increases at all engine speeds .Since the flame speed of hydrogen is five times as large as that of gasoline and the flammability range of hydrogen is much wider than gasoline, the hydrogen–gasoline mixture will have a faster burning velocity and an extended flame limit than gasoline, which can achieve a shorter burning duration and a more complete burning. Therefore, the faster flame speed of gasoline– hydrogen–air mixture leads to a higher degree of constant volume combustion, meaning that the engine operates much closer to the ideal cycle The maximum volumetric efficiency is attained for pure gasoline of about 70% at 4000 rpm compared to hydrogen gasoline operation. As the percentage of hydrogen blend increases there is a drop in volumetric efficiency due to the density difference between the air and hydrogen. Hydrogen being lighter than air displaces the air.

P. Selvi Rajaram et al.(2014)[7] They have carried out experiments in a Kirloskar make single cylinder, water-cooled, four stroke, direct injection (DI) diesel engine, developing a rated power of 5.9 kW at a speed of 1800 rpm and having a compression ratio of 17.5:1. For loading the engine, eddy current dynamometer was coupled to the

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engine. The OEH-HHO gas was metered out through a digital mass flow controller, in the engine oxygen enriched hho and diesel blends were inducted and result obtained by them are the brake thermal efficiency increases from 24.32% to 27.01%, by 11.06%. CO emission decreases by 15.38%.CO2 emission increased by 6.06%.NOx emission increased by 11.19% and unburned hydrocarbon decreased by 18.18% When 3.3 lpm of OEH-HHO gas was introduced into engine smoke reduced substantially by 26.19 %. However, when 1 lpm of OEH-HHO gas was introduced into a combustion process of diesel, the brake thermal efficiency decreased by 4.15%. NOx emission decreases from 226 ppm to 191 ppm, by a decrease of 15.48%. Smoke emission increases from 13 HSU to 14 HSU, by an increase of 7.69% and CO emission increases by an average increase of 7.69%

From this study, the effect of addition of hydrogen and HHO on IC Engines..Also shown that the effect of using hydrogen as an additive with conventional fuel as well as with biodiesel in the engine. For the complete combustion of petrol fuel, (HHO) has given better results. HHO gas was reduced the release of harmful gases like CO,HC and Smoke and NOx in some cases have reduced.. Out of various methods of hydrogen production were studied and economically electrolysis is found to be suitable method to produce HHO on board . Results found increase in brake power and brake thermal efficiency, reduction in specific fuel consumption and decrease emission of carbon oxides, oxides of nitrogen and unburnt hydrocarbon.

S. Wang et al.(2014)[8]A Beijing Hyundai-manufactured 1.6 L commercial spark-ignition engine with dual head placed camshafts was selected as the testing engine. The testing bench consists of an eddy current dynamometer, a combustion analyzer and an emissions analyzer. The hydrogen was introduced into cylinder through four hydrogen injectors placed on runners of each cylinder. A self-developed electronic control unit was adopted to control the hydrogen and gasoline injection timings and durations. The engine speed was adjusted to 1400 rpm. The engine throttle position was controlled to be fully opened. Two hydrogen volume fractions (αH_2) of 0 and 3% were applied. Imep of the 3% hydrogen-blended gasoline engine is lower than that of the original gasoline engine at two excess air ratios of 1.0 and 1.2, due to the low volume energy density of hydrogen. When the excess air ratio approaches to 1.4, Imep is raised after the hydrogen addition, this is because the hydrogen has a wider flammability limit than gasoline. Thus, the hydrogen-blended gasoline engine could be run smoothly at high excess air ratios. However, because of the narrow flammability of gasoline, the original engine suffers a slow burning or even incomplete combustion at high excess air ratios. Thus, although the gasoline-air mixtures have a higher energy density than the hydrogen-gasoline-air mixtures at a specific excess air ratio, Imep of the pure gasoline engine is still lower than the 3% hydrogen-blended gasoline engine at an excess air ratio of 1.4 due to the slow burning and incomplete combustion of gasoline.

III. CONCLUSION

Since Hydrogen has higher heating value and flame speed compared to conventional liquid fuels. Hydrogen enriched fuels in this study provide better brake torque outputs than neat diesel fuel and B10 and other biodiesel & diesel blends. HHO addition to petrol has increased fuel efficiency and reduction in CO, HC, and NOx emission. Also flow rates from higher LPM to low LPM affects the Brake power, BTE,Volumetric efficiency and Emission characteristics.Also reduction in manifold temperature is found in HHO addition with petrol. It can be concluded that HHO is an most suitable additive for improving performance and reduction of emissions.

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