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Hydrogen as an Alternative Fuel - An Overview

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Abstract: ***We are in the age when we always look for a better alternative of the current technologies. Of all the environmental issues faced by us one of the major problems is global warming caused by co_2 emission from vehicles (working on fossil fuel). Fossil fuels are depleting day by day and increase in price of petroleum (petrol & diesel) is also a big issue. Considering the entire problem we should move for the better alternative of fossil fuel which has less emission and provide better efficiency. Hydrogen has many unique properties which make it as a best alternative for fossil fuel. Hydrogen can also be used for generating the power to run the engine. In nature hydrogen is present in the form of chemical composition. There are number of techniques to extract hydrogen from its chemical compound, but the technique must be safe and environment friendly, steam reforming of natural gas is famous technique to get pure form of hydrogen.***

Keywords: Hydrogen fuel, alternative hydrogen fuel, H_2 fuel

1. Introduction

Hydrogen is the only alternative fuel that can be produced by many sources (water, Hydrocarbons, other domestic resource).Hydrogen is in its early stage of growth to become a transformational fuel for vehicle. Many industries are working in the direction of safe economical and clean production and distribution of hydrogen for fuel cell electric vehicle (FCEVS). FCEVs are the future of the automobile industry. Many companies are working on buses, handling equipment, medium and heavy duties vehicle, passenger vehicle application which are powered by hydrogen fuel. Hydrogen is present in environment in the form of chemical compounds, like water, hydrocarbons (CH_4) and other organic matter. Extracting hydrogen efficiently from this compound is challenging process. Steam reforming, producing hydrogen from hydrocarbons fuel such as natural gas. By electrolysis process on water hydrogen will be produced. This process is energy intensive but using renewable energy source process cost will be less.

Akhileshpati tiwari [1]: hydrogen is a very efficient fuel for automobile and atmosphere for its zero emission properties. Hydrogen powered vehicle is more efficient than conventional vehicle which uses fossil fuel.

Neap Singh [7]: Hydrogen fuel in vehicle can reduce the pollution. The only by-product of hydrogen after burning is water which is harmless.

2. Review of Paper

Akhileshpati tiwari [1] - to overcome the problem of fossil fuel presence. We need to develop a hydrogen engine. Available in abundant form in nature. It is highly combustible gas carries various properties. Which is more suitable to use as a fuel in engine? It produces less harmful effect. The limit of compression ratio is based on fuel resistance to knock. A lean hydrogen Mixture is less capable to knock than conventional gasoline and therefore can tolerate higher compression ratio. Compression ratio limit of an engine is depending on the fuels resistance to knock.

Table 1: Comparison of Properties of Hydrogen with Gasoline

Properties	H_2	Gasolie
Quenching gap in NTP air, cm	0.064	0.3
Auto ignition Temp, K	849	501-764
Flame Temperature in air, K	2318	2370
Stoichiometric composition in air, vol %	29.53	1.76
Limits of Flammability in air, vol %	4-65	1.0 -7.6
Burning Velocity in NTP air, cm/s	325	34-63
Normalized Flame Emissivity	1.0	1.7
Equivalence ratio flammability limit in NTP air	0.1-7.1	0.7-3.8

A lean hydrogen Mixture is less affected to knock than ordinary gasoline and therefore can accept higher compression ratio. The specific heat ratio is related to the fuel molecule arrangement. The less complicated molecule structures the greater the specific heat ratio. The atomic arrangement of hydrogen (Y=1.4) is greater than gasoline and thus its specific ratio is greater than that of conventional gasoline (Y=1.1). In gasoline engine the devaluation in Kn_{ox} is negotiate by an increase in carbon-mono-oxide and hydro-carbons. Theoretical maximum power output of hydrogen engine depends on the air/fuel ratio and fuel injection system.

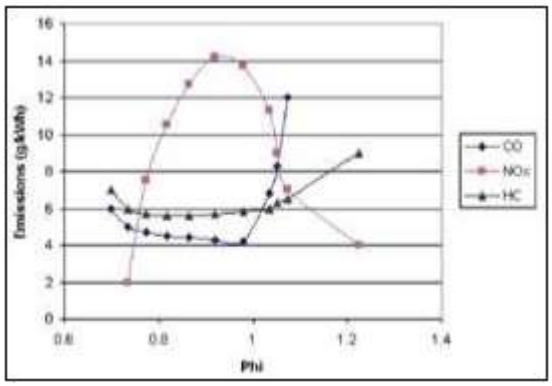

Figure 1: co, No, HC Emission

For hydrogen air/fuel ratio is 34:1 in combustion chamber hydrogen displace 29% of the combustion chamber leaving only 71% for the air. Hydrogen is low exhaust emission

design of hydrogen engine is not follow the stoichiometric air/fuel ratio. Hydrogen engine is larger than gasoline engine turbo-charger & super-charger is used. Use of hydrogen gives clean environment.

Ankit moroli [2] gasoline engine exhaust maximum cause the global warming and drastic change in temperature. In order to reduce this we need to switch or go for an alternative fuel or energy source. Hydrogen can be replacing the conventional fuel

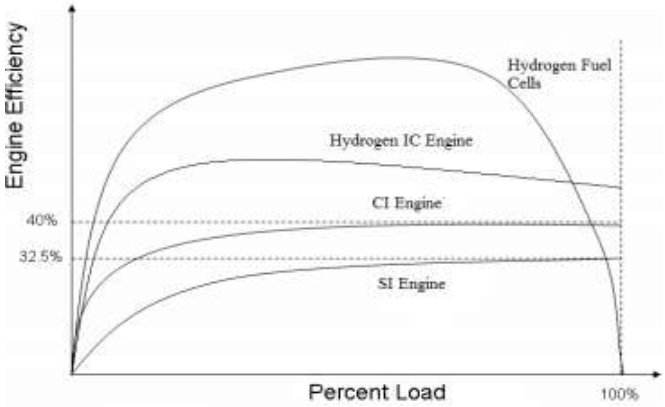

Figure 2: Engine Efficiency vs. percent load

Thus THE hydrogen powered vehicle is the future of the automobile industry. There is many research remain to be done on this RESEARCH. There is

Table 2: Types of fuel Used in Engine

	GASOLINE INTERNAL COMBUSTION ENGINE	GASOLINE HYBRID	HYDROGEN INTERNAL COMBUSTION ENGINE	HYDROGEN FUEL CELL
ENGINE TYPE	SPARK-IGNITION	SPARK-IGNITION & ELECTRIC MOTOR	COMPRESSED IGNITION (WITH ELECTRIC MOTOR)	FUEL CELL & ELECTRIC MOTOR
AVERAGE ENGINE EFFICIENCY	~30%	~30%	~40%	~55%
MAX ENGINE EFFICIENCY	32.5%	32.5%	~40%	~65%
TRANSMISSION TYPE	STANDARD	CONTINUOUSLY VARIABLE TRANSMISSION/ HYBRID	CONTINUOUSLY VARIABLE TRANSMISSION/ LIKELY HYBRID	CONTINUOUSLY VARIABLE TRANSMISSION / LIKELY HYBRID
TRANSMISSION EFFICIENCY	~40%	~60%	~60%	~60%
FUEL ECONOMY (MILES PER GALLON EQUIVALENT.)	21	31	41	51

No mass production of fuel cell so the future of hydrogen IC engine in very LARGE SCALE. All we can say hydrogen is the best alternative COMPARE TO OTHERA FOSSILE FUELS.

In hydrogen fuel cell vehicle study-[3]
Table 3:- fuel Economy, engine use and co_2 Emission for Alternative Fuelled automobile

	FUEL ECONOMY Mpg equiv- LHV basis (from GREET model, except fuel cell vehicles and H_2 ICE/HEVs from DTI)	Well to Wheels Energy Consumption (BTU/mi)	Well to Wheels CO_2 emissions (g/mile)
IC ENGINE VEHICLES			
Conventional Gasoline SI Engine	22.4	6492	514
CNG SI Engine	20.3	6702	459
Adv. Diesel CI Engine	37.0	4365	378
ICE/HYBRID VEHICLES			
Gasoline SIDI HEV	46.8	3097	253
CNG SI HEV	48.6	2867	196
Ethanol SIDI HEV	46.9	4921	67
H_2 SI HEV	**50.0**	3466 w/o CO_2 seq 3380 w CO_2 seq	234 w/o CO_2 seq 43 w/ CO_2 seq
Diesel CIDI HEV	56.8	2487	208
FUEL CELL VEHICLES			
Gasoline (probable)	**38.0**	3819	304
(best)	**49.4**	2938	234
Methanol (probable)	**56.0**	3212	199
(best)	**64.2**	2802	174
Hydrogen (from natural gas with steam reforming, pipeline delivery and compression to 5000 psi for onboard storage	**52.0**	2368 w/o CO_2 seq 2448 w CO_2 seq	143 w/o CO_2 seq 25 w CO_2 seq

The following reaction takes place in fuel cell:-
Anode: $2H_2 + 4OH- \rightarrow 4H_2O + 4e-$
Cathode: $O_2 + 2H_2O + 4e- \rightarrow 4OH-$
Overall cell reaction: $2H_2 + O_2 \rightarrow 2H_2O$

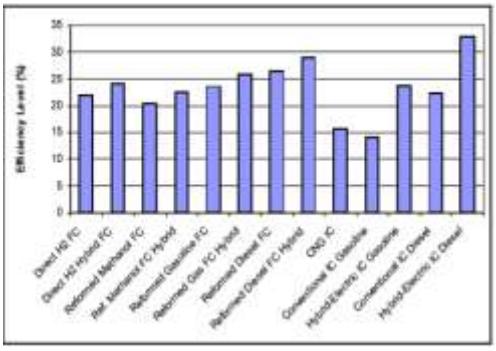

Figure 3: Comparison of energy for fuel cells, internal Combustion and Hydrogen vehicle

The efficiency of fuel cell is 60% to 70%. But when we consider the overall efficiency then it is near about 30% only. When production of hydrogen is from hydrocarbons. The overall efficiency of IC engine is near about 15% , hybrid electric gasoline engine efficiency is 25%.when hydrogen production by natural energy source by electrolysis process then the overall efficiency become 50%. Storage of hydrogen is still a big issue to focus. A MIT study says that the fuel cell vehicle don't have sufficient advantage over hybrid-electric vehicle, internal combustion engine.

Adam campisi [4] – hydrogen fuel cell most widely used in vehicle. Hydrogen cell is not available in mass for next 15-20 year.

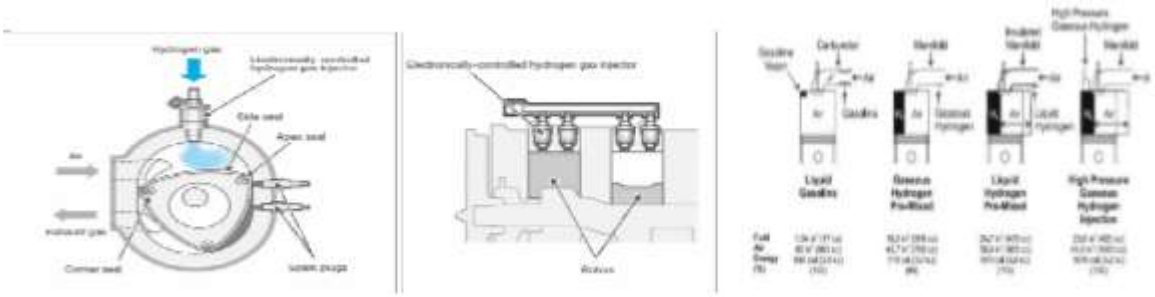

Figure 4: fuel used in engine

Hydrogen internal combustion engine (HICE) is more effective for immediate solution with inexpensive, easy to install and no harmful emission. Gives high efficiency than gasoline engine.

ARK A DELUCHI [5]: Hydrogen is least pollution fuel in nature can be produced by water and electricity. Hydrogen fuel cell powered electric motor vehicle (FCEV) is the bright future of automobile. Zero emission high efficiency long life

Table 4: Percentage change in gm/km emission from alternative-fuel light-duty vehicles, relayed to gasoline vehicle, year-2000

Feedstock/Fuel/Vehicle	Criteria Pollutants[b]					Greenhouse Gases[c]
	NMOC	CO	NO_x	SO_x	PM	
U.S. power mix/BPEV[d]	−95	−99	−56	+321	+153	−37
NG/compressed hydrogen/FCEV	−100	−100	100	−100[e]	−100	−65
Biomass/compressed hydrogen/FCEV	−100	−100	−100	−100[e]	−100	−84
Biomass/methanol/FCEV[f]	−90	−99	−99	−100[e]	−100	−89
Solar/compressed hydrogen/FCEV[g]	−100	−100	−100	−100[e]	−100	−94
Solar/compressed hydrogen/ICEV	−95	−99	−?[h]	−100[e]	lower	−89
Solar power/BPEV	−100	−100	100	−100	−100	−100
Baseline emissions on gasoline, g/km	0.48	3.81	0.28	0.035	0.01	282.5

If fuel cell and electric drive system develops then hydrogen FCEVs will have same life cycle as gasoline engine. Hydrogen FCEVs available at low price then gasoline. Hydrogen FCEVs having zero emission, which is attractive towards the environment

IBRAHIM DINCER [6]: the paper shows the future aspects of hydrogen & fuel cell. The fuel and cell hydrogen ICE plays an important role in future of less emission vehicle for a market respective. The hydrogen and fuel cell are most likely and early to growth. The better environment because of zero exhausts emission.

Table 5: Number of patents for various year ranges

Query keyword	Year range	Number of patents
Hydrogen energy	1963-2007	10,576
Fuel cell	1963-2007	47,120
Hydrogen energy	2000-2007	5,228
Fuel cell	2000-2007	34,756

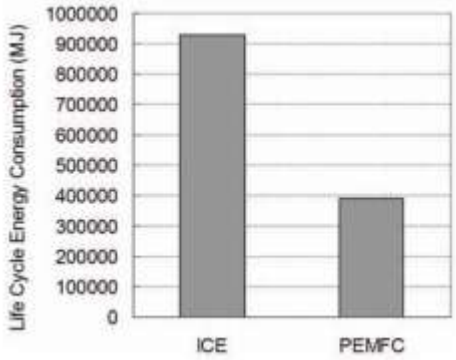

Figure 4: Life cycle energy consumptions

By using thermodynamics principles we can highlight the benefits of hydrogen & fuel cell.

1) As we are looking for an ultimate fuel it requires to be free from environmental problem and less exhaust should remain after combustion having almost zero impacts on air and water.
2) The hydrogen and fuel cell requires to supply and full fill the energy requirement at low cost and follow all the safety criteria. There are different energy source like solar wind hydro and bio mass are consider as renewable energy source. IF we use these non-renewable source for generation of hydrogen will be more beneficial.
3) For hydrogen development if we use the renewable energy resource then there is less chance of pollution. Use of hydrogen cell can be replacing the gasoline engine.
4) Use of fuel cell and hydrogen engine provider a better efficiency.

Neap Singh [7]: By fossil fuel consumption, now we faced the problem of Global Worming and environment pollution. This environment pollution impacts a Human Health. If we continuously focused on Better alternative which has zero ambition the molecule of fuel is become smaller in size and hydrogen molecule is richer in size. Methane as a fuel is a greater move in the way of fondly better alternative. After burring methane there is no any after burnt product remain which may cure any harmful effect. Here hydrogen is also a better opinion due to its high combustion nation and zero exhaust which may solve the problem of environment pollution and also take care of human health. When we use hydrogen in engine the water is only the by-product hydrogen is best option for automobile. When the production of Hydrogen source which is available in nature. Water is the best form to generate the Hydrogen. We can use the Renewable sources of energy for Hydrogen Production. Before implemental the hydrogen as fuel is Automobile we

must focus on the cost of Generation of Hydrogen and Storage. Hydrogen may have potential to replace the fossil fuel. And become the future fuel. The production of Hydrogen is a best opportunity for a Company Business. They can use Renewable energy sources foe producing the Hydrogen. Hydrogen is order less, test less, non-toxic and colourless gas. Hydrogen is more flammable beyond and diffusive. Density of Hydrogen is also very low due to its lightness another are problem of storage and transport of Hydrogen.

Hydrogen as an alternative fuel [8]:- Hydrogen is the alternative source of the energy for fossil fuel (HC) .We can produce energy form fuel cell for producing hydrogen then are number of process like fermentation and nature gas reforming. It is an environmental friendly energy. Storage of hydrogen is the main issue. To get the pure form of hydrogen is expensive process. Hydrogen fuel cell is a best alternative to get energy for car boats and home application in future.

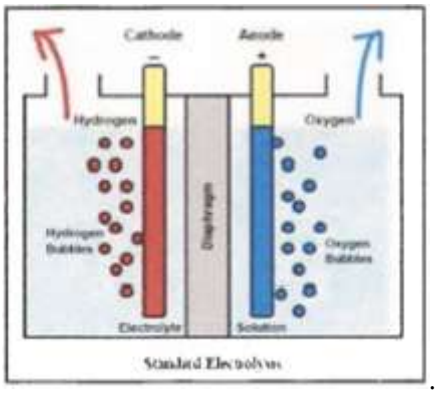

Figure 5: Hydrogen production using electrolysis

One of the companies Toyota using fuel cell in their future generation of vehicle. It only needs some safety areas to cross. California started to produce the hydrogen station for cars using hydrogen fuel cell like electric car station. Use of hydrogen as a fuel for vehicle reduce the ozone layer and also impact on global warming and gives the better environment and give provide a better future.

RACHEL CHAMOUSI [9]- Hydrogen fuel can be replaces the fossil fuel and become the hydrogen economy. Hydrogen or fuel cell is a pollution free (emission free fuel) Due to low density of hydrogen the storage and transportation is a question to be answer. For a clean environment, we have to use of natural source of energy for hydrogen generation. And we can say hydrogen will be the future fuel. When we go for alternative fuel than the fuel must be technically feasible economically vibe cost friendly and can convert to another energy form When combustion.

Table 6: Hydrogen percentage in different metal

Metal	Hydride	% Hydrogen by mass	Equilibrium Pressure (bar)	Equilibrium Temperature (K)
Pd	$PdH_{0.6}$	0.56	0.020	298
$LaNi_5$	$LaNi_5H_6$	1.37	2	298
ZrV_2	$ZrV_2H_{5.5}$	3.01	10^{-8}	323
FeTi	$FeTiH_2$	1.89	5	303
Mg_2Ni	Mg_2NiH_4	3.59	1	555
TiV_2	TiV_2H_4	2.60	10	313

And safe for all aspect for human and nature as well. Presence of hydrogen is grate in nature but it is not in a pure form. We need to process it to get pure form for this we have different- different process. Hydrogen can be use in normal ICE. The polymer electrolyte member (PEM) fuel cell provides the grate efficiency. Hydrogen can produce the water combine with air (oxygen).For hydrogen production use of renewable energy source may cause less emission and pollution free environment. In fuel cell car 2009 Honda FCX clarity 1kg of provide about 68mile of travel. We have to find less costly process to produce the hydrogen. The use of hydrogen causes no greenhouse emission. Only problem with hydrogen is storage and transportation due to low density. If we can use renewable source of energy for hydrogen generation than it is more economical approach. For implementing the hydrogen into vehicle need some more research to be done. Some safety criteria to be focused. By using PV cell we get sufficient amount of electricity for producing the hydrogen, it gives more efficiency and less costly process comparing to other hydrogen generation process. This process call as SOLAR HYDROGEN ENERGY.

J. S. WALLAC [10].-Hydrogen has number of attractive features which makes it best alternative fuel for future. Hydrogen produced by electrolysis process which is powered by electricity or nuclear-generated electricity. Hydrogen if a carbon free fuel, after burning there is no any harmful emission happen. Hydrogen based internal combustion engine is more efficient then gasoline fuelled engine. Storage of hydrogen is a big issue. Fuel cell has high efficiency then gasoline engine at particular loading condition

Table 7: Hydrogen storage as a cryogenic liquid

	Hydrogen	Gasoline[b] (Energy-Equivalent)
Fuel Mass (kg)	13.6	37.3
Fuel Volume (ℓ or $10^{-3}m^3$)	192.6	51.8
Total Weight,tank+fuel(kg)	56.4	51.5[c]
Total Volume,tank+fuel (ℓ or 10^{-3} m^3)	337.3	56.9[c]

Miqdam Tariq Chaicha [11].Hydrogen will become the future fuel and energy source for much energy application. The safety is very important area to focus. The use of the hydrogen will be safe. Hydrogen has low liquid state temperature (-212°C). Hydrogen is very sensitive gas it could cause thermal decline and condensation.

Table 8: Flammability, detonability and ignition properties of fuels

Fuel	H_2	CH_4	C_3H_8	Gasoline
Flammability limits				
Lower (%fuel per volume)	4.0	5.3	2.1	1.0
Upper (% fuel per volume)	75.0	15.0	10.4	7.8
Detonability limits				
Lower (%fuel per volume)	18.3	6.3	3.4	1.1
Upper (% fuel per volume	59	13.5	6.7	3.3
Ignition energy (mJ)	0.02	0.29	0.31	0.24
Thermal autoignition (°C)	520	630	450	
Minimum Heated laminar air jet (1mm d)	640	1040	885	
Heated Nichrome wire (1mm d)	750	1220	1050	

The fuel is safe to use at some application of hydrogen it is found that hydrogen is more safe then conventional fuels can replace all the Hydrogen fundamental fuel. In many industrial process hydrogen is consider as an essential substance. It handled and transferred successfully.

Transferring of hydrogen by pipe is safe and there is no any edition problem while transferring, for cooling the rotor hydrogen is used in many industry .hydrogen is most important alternative fuel for bus locomotive marine aeroplane and containers.

Mordechai Ben Menachem [12] .we can use hydrogen as an energy source, which improves the efficiency at low cost comparing to fossil fuel. As a costumer view use of hydrogen is beneficial .in order to understand the consumption of hydrogen there is a business model which is depends on consumers demand. The need of hydrogen as fuel for automobile will increase in near future. Hydrogen is be available in gases form. In near future hydrogen production will become a large business market. Hydrogen is also used by many industries for their different operations. Scaling and safe hydrogen production IS BARRIERS to remove.

Table 9: Unit conversion data for hydrogen

	Weight		Gas		Liquid	
	Pounds (lb)	Kilograms (kg)	Cubic feet (cf)	cu meters (m3)	Gallons (gal)	Litres (l)
1 lb	1	0.4536	192	5.047	1.6928	6.408
1 Kg	2.205	1	423.3	11.126	3.377	14.13
1 cf gas	0.00521	0.00236	1	0.02628	0.00882	0.033
1 m3 gas	0.19815	0.08988	38.04	1	0.3355	1.27
1 Gallon liquid	0.5906	0.2679	113.4	2.981	1	3.785
1 Litre liquid	0.15604	0.07078	29.99	0.7881	0.2642	1

To put this entire issue into perspective: the project discussed is in improved design of the site and logistics. All the designs are complete. A great idea is needed for powering large vehicles. The project does not produce any toxic gases it gives off one hundred percent non toxic clean hydrogen, in carbon neutral manner.

It also reduces extra garbage on the earth, which is one of the biggest problems on earth at present which needs to be looked at. And reduction in the amount of garbage is compulsorily required.

This process can be fully repeated and measured. And most importantly this is the first method in the world to do so.

Shivaprasad KV [13] Fast depletion of fossil fuel cause the urgency of alternative fuel to fulfill ecological energy requirement. Here is the description of hydrogen in S I engine as a fuel. Use of hydrogen in the spark ignition engine can be achieved by upgrading the present technology using advanced modifications.

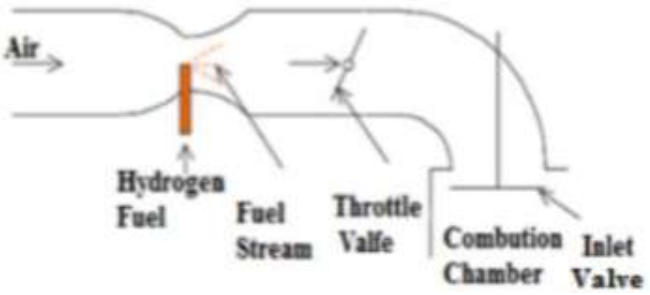

Figure 6: Fuel Carburetion Method

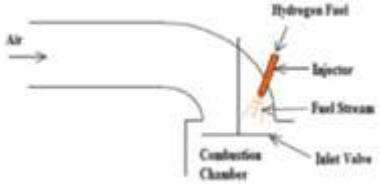

Figure 7: Inlet Manifold/Inlet Port Injection

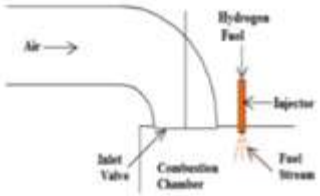

Figure 8: Direct Injection System

The problem of depletion of fossil fuel and the pollution caused by that can be solved by the introducing hydrogen as a fuel for spark ignition engine. Use of hydrogen in internal combustion engine is very promising and can be expected to provide high efficiency, improved power density, and less emission. Arinola B. Ajayi [14] Hydrogen is generated by electrolysis of water. The shape of hydrogen generator is cylindrical and screwed by cover both made by same material. Lead is present as electrode. We can use old battery to get lead. Distilled water with the presence of sodium hydroxide is used as an electrolyte.27liters of hydrogen gas is produced by 60 amps current continuously passing through electrolyte by 30 minutes. The hydrogen generator can be made by any material which is available. Hydrogen gas can replace gasoline fuel to develop the electricity at small scale. The hydrogen generator can easily mirror hydrogen is most promising and sustainable fuel for future. Hydrogen also be use in engine as a fuel

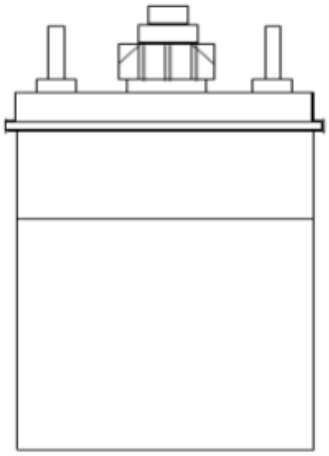

Figure 9: Hydrogen generator for hydrogen gas production.

3. Review

Hydrogen fuel is sustainable fuel source for the upcoming future. The main trouble with hydrogen is getting the pure form, from its chemical compound.

In electrolysis process platinum is use as an electrode to create hydrogen fuel. Platinum is most expensive metal for purification of hydrogen gas. Hydrogen measures in miles per kilogram. 1kg of hydrogen is equal to 3.785litres of gasoline. The price of hydrogen is about 62 Rs per kg, which is less than the current price of gasoline. Hydrogen as in the form of fuel is available in limited areas and very less hydrogen station are available.

Hydrogen's simple structure cause the hydrogen engine doesn't have much power. So compared to gasoline or diesel both are nearly same in price. Fuel cell vehicle where hydrogen is used are very expensive car. So the overall cost of hydrogen production and implementation should decrease as technologies improve.

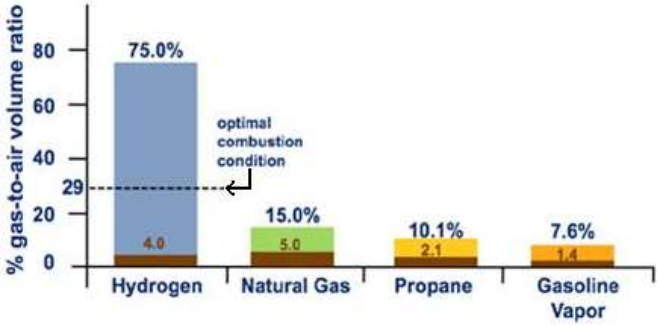

Figure 10: Comparative efficiencies of Fc, Diesel, Petrol D.A.R.T. and H.A.R.T

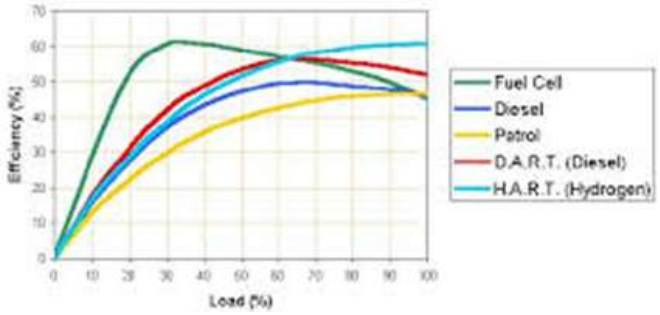

Figure 11: % GAS-To-air volume ratio

4. Conclusion

Like coal and gas Hydrogen isn't a primary energy source. H_2 is an energy carrier. Hydrogen and fuel cell is the best alternative of the Fossil fuel, using renewable source of energy for hydrogen generation. Hydrogen fuel is highly efficient as compared to conventional fossil fuel. Hydrogen as an alternative fuel is a step toward renewable energy generation. Burning hydrogen fuel doesn't releases any kind of toxic gases because of the absence of carbon particle; this makes hydrogen as a zero pollution fuel.

Hydrogen fuel vehicle is a clean transport which doesn't deplete the air quality in polluted cities. And helps the environment to remain at stable state. Like coal and gas Hydrogen is not a primary energy source. H_2 is an energy bearer. In coming future hydrogen will be as important and as safe as some of our major energy source like electricity. We can use hydrogen to its full potential by developing a complete infrastructure for this fuel system. Hydrogen is very promising alternative fuel for automobile industries and also for other application.

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