iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IV **Month of publication:** April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4271

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Design and Fabrication of Two Stroke Engine using Hydrogen as Fuel

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Abstract: Hydrogen can be used in different configurations of Internal Combustion (IC) engine such as spark ignition (SI) engine, compression ignition (CI) engine /dual fuel engine, CNG dual fuel engine and Homogeneous charge compression ignition (HCCI) engine. High power outputs and low NOx emissions can be achieved by direct injection of hydrogen in SI engine. Hydrogen may also be used with biogas or other low grade gaseous fuels in this mode for the applications in locomotives and in stationary power generation. Hydrogen can be a good additive in the case of biogas diesel HCCI operation, as it raises the efficiency and extends the load range. Engine control units for dual fuel, HCCI and direct hydrogen injection engines with effective control strategies, in some cases to switch between modes have to be developed. There is need to develop after treatment device for NOx reduction (Lean NOX trap, SCR etc.), which will be helpful in improving power output while engine operates at a higher equivalence ratio. This is very relevant for heavy duty engines operating on hydrogen. The application of hydrogen blends with various fuels like CNG, LPG, Diesel etc. also need to be studied.

Keywords: SI, CI Engine, HCCI, NOx

I. INTRODUCTION

At the present day, where the supplies of the fossil fuels are decreasing and increase in the concentrations of atmospheric carbon dioxide as well as atmospheric pollutants are some of major challenges to the modern society. The scientific community is addressing these problems by an attempt to replace fossil fuels with cleaner and renewable sources of energy such as solar powered vehicles, electric cars. But we have seen that this are either non-reliable, costly or lags the technical advancement and convenience which is provided by the petroleum fuel vehicles. So the idea is not to compete with petroleum fuels but to increase the life of petroleum fuels to exist longer in this ever demanding automobile industry. Every buyer has a mind set to have a vehicle with great looks, good performance and high efficiency. But unfortunately, even with the latest technology, it is difficult to achieve the perfect balance between performance and price. So in order to conserve petroleum fuels for future and to eliminate the aforementioned limitations, there is a need of alternative and innovative fuel. The oxy-hydrogen gas is obtained by the simple process of electrolysis of water, which has high calorific value which can be used in addition to petrol. In this research work, the oxy-hydrogen gas is used in four stroke petrol engine for better performance and lower emission values. The current energy crisis urges us to explore a variety of alternate methods to satisfy the world's energy demands. A major market solution for the energy crisis is increasing supply and reducing demand for crude oil. By increasing the list of feasible fuel alternatives, the demand on crude oil reduces. Among all the potential environment-friendly alternative fuels of the future, hydrogen is one of the most promising in terms of practicality, long term feasibility and low pollution levels. Thus it has the capability to contribute majorly towards solving two major issues: energy security and climate change. Hydrogen has a very low energy density when compared to gasoline. This is a disadvantage for storage, transport and safety purposes since it will need to be stored at very high pressures. In addition, hydrogen cannot be used to produce energy by combustion at temperatures below 0 celsius, since the fuel requires a higher temperature to burn. Therefore the challenge becomes storing hydrogen at extremely high pressures without drastically reducing the temperature

A. Hydrogen Fuel

In a flame of pure hydrogen gas, burning in air, the hydrogen (H_2) reacts with oxygen (O_2) to form water (H_2O) and heat. It does not produce other chemical by-products, except for a small amount of nitrogen oxides. Hence a key feature of hydrogen as a fuel is that it is relatively non-polluting (since water is not a pollutant). Pure hydrogen does not occur naturally; it takes energy to manufacture it. Once manufactured it is an energy carrier (i.e. a store for energy first generated by other means). The energy is eventually delivered as heat when the hydrogen is burned. The heat in a hydrogen flame is a radiant emission from the newly formed water molecules. The water molecules are in an excited state of initial formation and then transition to a ground state, the transition unleashing thermal radiation. When burning in air, the temperature is roughly 2000°C. Hydrogen fuel can provide motive power for cars, boats and aero planes, portable fuel cell applications or stationary fuel cell applications, which can power an electric motor.

The current leading technology for producing hydrogen in large quantities is steam reforming of methane gas (CH_4). Other methods are discussed in the Hydrogen Production article. Primarily because hydrogen fuel can be environmentally friendly, there are advocates for its more widespread use. At present, however, there is not a sufficient technical and economic infrastructure to support widespread use. The proposed creation of such an infrastructure is referred to as the hydrogen economy.

At the gas pressure that hydrogen is typically stored, hydrogen requires four times more storage volume than the volume of gasoline that produces the equivalent energy, but the weight of this hydrogen is nearly one third that of the gasoline. With regard to safety from unwanted explosions, hydrogen fuel in automotive vehicles is at least as safe as gasoline. The advantages and disadvantages of hydrogen fuel compared to its competitors are discussed at hydrogen economy.

B. Hydrogen Internal Combustion Engine Vehicle

A hydrogen internal combustion engine vehicle (HICEV) is a type of hydrogen vehicle using an internal combustion engine. Hydrogen internal combustion engine vehicles are different from hydrogen fuel cell vehicles (which use hydrogen + oxygen rather than hydrogen + air); the hydrogen internal combustion engine is simply a modified version of the traditional gasoline-powered internal combustion engine.

C. Low Emissions

The combustion of hydrogen with oxygen produces water as its only product:

$2H_2 + O_2 \rightarrow 2H_2O$

The combustion of hydrogen with air can also produce oxides of nitrogen, though at negligibly small amounts. Tuning a hydrogen engine to create the most amounts of emissions as possible results in emissions compared with consumer operated gasoline engines since 1976.

$H_2 + O_2 + N_2 \rightarrow H_2O + N_2 + NOx$

D. Adaptation of Existing Engines

The difference between a hydrogen ICE from a traditional gasoline engine could include hardened valves and valve seats, stronger connecting rods, non-platinum tipped spark plugs, higher voltage ignition coil, fuel injectors designed for a gas instead of a liquid, larger crankshaft damper, stronger head gasket material, modified (for supercharger) intake manifold, positive pressure supercharger, and a high temperature engine oil. All modifications would amount to about one point five times (1.5) the current cost of a gasoline engine. These hydrogen engines burn fuel in the same manner that gasoline engines do. The power output of a direct injected hydrogen engine vehicle is 20% more than in a gasoline engine vehicle and 42% more than a hydrogen engine vehicle using a carburetor. Hydrogen internal combustion engine cars are different from hydrogen fuel cell cars.

II. COMPONENT

COMPONENTS	QUANTITY	MATERIAL
TVS XL ENGINE	1	
BASE FRAME SET UP	1	MILD STEEL
COMPRESSED TANK FOR HYDROGEN	1	MILD STEEL
WATER STORAGE TANK	1	MILD STEEL
ELECTODE	2	COPPER
PRESSURE VALVE	1	
WHEEL	1	
CONTROL UNIT	REQUIRED	
SEAT ARRANGEMENT	1	PLYWOOD
BATTERY	1	

A. Engine

The TVS XL 100 is powered by a 99.7 cc air-cooled single-cylinder four-stroke engine that is tuned to produce 4.2 PS of maximum power at 6,000 rpm and 6.3 Nm of peak torque at 3,500 rpm. It is capable of delivering a fuel economy of 67 km/l (under simulated test conditions), and has a claimed top-speed of 60 km/l. The engine is mated to a single-speed gearbox via a Centrifugal Wet Type clutch.

The XL 100 is equipped with a telescopic fork, swing arm with hydraulic shocks, 80 mm drum brake upfront, 110 mm drum brake at the rear, 2.5 X 16 inch tyres mounted at a wheelbase of 1,215 mm, a four-litre fuel tank (with a 1.3-litre reserve), and halogen type headlamp, indicators and taillamp. The moped has a dry weight of 75 kg and a payload of 130 kg.

Hydrogen is the lightest element on the periodic table. Its monatomic form (H) is the most abundant chemical substance in the Universe, The universal emergence of atomic hydrogen first occurred during the recombination epoch. At standard temperature and pressure, hydrogen is a colorless, odorless, tasteless, non-toxic, nonmetallic, highly combustible diatomic gas with the molecular formula H_2.

B. Battery

We stock the top-quality brands of AGM and Gel-type SLA batteries to give you the best power options and offer only the highest performing, top-quality SLA Sealed Lead Acid Batteries around.

C. Wheel

A wheel is a circular component that is intended to rotate on an axle bearing. Common examples are found in transport applications. A wheel greatly reduces friction by facilitating motion by rolling together with the use of axles.

III. HYDROGEN

A. Hydrogen Production

1) Current technologies for manufacturing hydrogen use energy in various forms, totaling between 25 and 50 percent of the higher heating value of the hydrogen fuel, used to produce, compress or liquefy, and transmit the hydrogen by pipeline or truck.
2) Environmental consequences of the production of hydrogen from fossil energy resources include the emission of greenhouse gases, a consequence that would also result from the on-board reforming of methanol into hydrogen.
3) Studies comparing the environmental consequences of hydrogen production and use in fuel-cell vehicles to the refining of petroleum and combustion in conventional automobile engines find a net reduction of ozone and greenhouse gases in favour of hydrogen.

B. Hydrogen Distribution

1) The hydrogen infrastructure consists mainly of industrial hydrogen pipeline transport and hydrogen-equipped filling stations like those found on a hydrogen highway. Hydrogen stations which are not situated near a hydrogen pipeline get supply via hydrogen tanks, compressed hydrogen trailers, liquid hydrogen trucks, or dedicated onsite production.
2) Hydrogen use would require the alteration of industry and transport on a scale never seen before in history. The distribution of hydrogen fuel for vehicles would require new hydrogen stations costing billions of currency in each country.

C. Working Principle

The hydrogen gas is produced by mixing the KOH and water with the help of cathode and anode terminals. This is called Fuel cell arrangement. A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained. Fuel cells are different from conventional electrochemical cell batteries in that they consume reactant from an external source, which must be replenished – a thermodynamically open system. By contrast, batteries store electrical energy chemically and hence represent a thermodynamically closed system. Figure 4.1 shows the working principle of the hydrogen car.

IV. CALCULATIONS

A. Calculation of Engine Capacity

1) Analytical Design
2) From Tvs Engine

Speed (N1) = 900 rpm
Number of teeth on sprocket(z1)=14
Number of teeth on sprocket(z_2)=43
Where;
N - Transmitted power in Kw,
N1 -smaller sprocket speed, rpm
N2 - Larger sprocket speed, rpm

B. Speed Reduction Ratio

From design data book, (Pg no. 7.74) Chain sprocket design,
Recommended value of i for Z_1 = 14, Z2 = 43,
Z2 = i Z1
i=Z_2 / Z_1
i=43 / 14
i=3 (approx)
Where;
i = speed reduction ratio

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Z1=No of teeth on sprocket pinion
Z2=No of teeth on sprocket wheel

C. Calculation Of Speed(N2)

i = N1 / N2
3 = 900/N2
N2 =300 rpm
Where
i = speed reduction ratio,
N1 -smaller sprocket speed, rpm
N2 - Larger sprocket speed, rpm

D. Calculation Of Pitch

From design data book, (Pg no. 7.74) Chain sprocket design,
Centre distance,
a = (30 to 50) p,
Assume,
a = 500mm
PMAX = a / 30 = 500/30 = 16. 67mm
PMIN = a / 50 = 500 / 50 = 10mm
From design data book, (Pg no. 7.74) Chain sprocket design,
From the table in between 10 and 16.67 mm
Selected standard PITCH (P) = 15.875 mm
Where ;
a = centre distance, mm
P = pitch, mm

E. Centrifugal Tension

Pc = w.v2 / g
From(pg 7.72) w = 1.01 kgf
= 10.1 N
Therefore,
PC = 10.1x 15.8752 / 9.81
PC = 259.46 N
Where;
PC – centrifugal tension, N
w – weight per meter of chain, N
v – chain velocity, m/s

F. Tension Due To Sagging Of Chain

Ps = Ks.w.a
'K' form DDB, Pg. 7.78, for horizontal (or) upto 90 o Chain position,
Constant load, Load factor, KS= 1.15
Therefore, Ps = 1.15 x 10.1 x 0.5
Ps = 5.8075 N
Therefore Total load ,
PT = 132.09 + 259.46 + 5.8075
PT = 397.36 N

Where;
PT=Total load on the driving side ,N
Pt=Tangential force durind the power transmission,N
PC=Centrifugal tension,N
PS=Tension due to sagging of chain,N
V=Chain velocity, m/s
W=Weight per metre of chain,m/s

G. Calculation of Design Load

1) Design load = PT x Ks
= 397.36 x 2.344
= 931.42 N
Where ;
PT-Total load on the driving side, N
KS -service factor

H. Length Of Chain (L)

From design date book Pg no. 7.75 in DDB
lp = 2aP + ((Z1 + Z2) / 2) + (((Z2 – Z1) / 2)2 / 40)
ap = a0/p
=150/15.875
=31.5
lp = 2 x31.5+ ((12 + 84) / 2) + (((84 – 12) / 2)2 / 40)
number of links, lp = 111.89 ≈ 112
L= lp x p =112 x15.875=1778mm

I. Diameter Of Sprockets

From design data book Pg no. 7.78,
d1 = p / sin (180/Z1) = 61.33mm
d2 = p / sin (180/Z2) = 242mm.
Where;
d1 –small sprocket diameter
d2 –larger sprocket diameter

J. Calculation of Battery capacity

The basic formula for determining distance is:
Distance = (KWh of pack / wh/m)
Watt-Hour per Mile (Wh/m):
The basic rule of thumb for vehicle is:
Required start of Vehicle 250-300wh/m
Required Pickup of Vehicle 350-400wh/m
The calculation is: Volts x (Amp Draw / MPH) = Wh/m
Battery Pack Size (KWH):
Pack Voltage x Amp-Hour rating of battery = KWH
Usable Pack size: KWh x 0.80 x Peukerts = Usable KWh
Peukerts:
Lead-Acid = 0.55
LiFePO4 = 1.0
Available power when using Lead-Acid.
Putting all this together
Batteries: 12V Lead-Acid, rated at 100 ah

Charge booster 12v
Pack Voltage: 24V ((1 batteries x 12V) + 12v each = 24V)
Pack Size: 14.4 Kwh
Usable Pack: 6.336 Kwh
From experience, we know that using a 144V system will draw around 90amps at 50MPH.
Therefore, the Wh/m usage = 24V x (90Amps / 50MPH) = 43.2Wh/m
Performance
Now we get to the fun part, calculating HP
V x A = watts, and watts/746 = HP so V x A / 746 = HP
If we had a 24 volt pack of 15ah batteries, and a 10 amp controller,
V x A = watt
24 x 15= 360 watt

K. output

1) Performance characteristics
a) Brake Mean Effective Pressure (Bmep)
b) Brake thermal efficiency
c) Volumetric efficiency
2) Emission characteristics
a) Carbon monoxide (CO) emission
b) Hydrocarbons (HC) emission
c) Nitrogen oxide (NOX) emission

V. CONCLUSION

A significant improvement in total vehicle efficiency through an advanced hydrogen ICE design will impact on the volume of H2ICE powered vehicles in operation in a future hydrogen economy. The development of a suitable IC engine design specifically for hydrogen fuel is yet to be undertaken and the potential to achieve a viable, long term outcome is therefore unknown. The lower thermal efficiency of even the ideal hydrogen IC engine as compared to current fuel cell technologies must be weighed against the full life cycle cost from manufacture to disposal of the H2ICE. The hydrogen internal combustion engine has a long way to go and converting current four-stroke automotive engines to operate on hydrogen will not provide us with a benchmark that gives an indication of the full potential of the hydrogen ICE. The important decision is to invest R&D dollars into a design which has an inherent capability of meeting the target requirements. The bright side is that it could be relatively inexpensive to explore and the result can be better than is currently anticipated.

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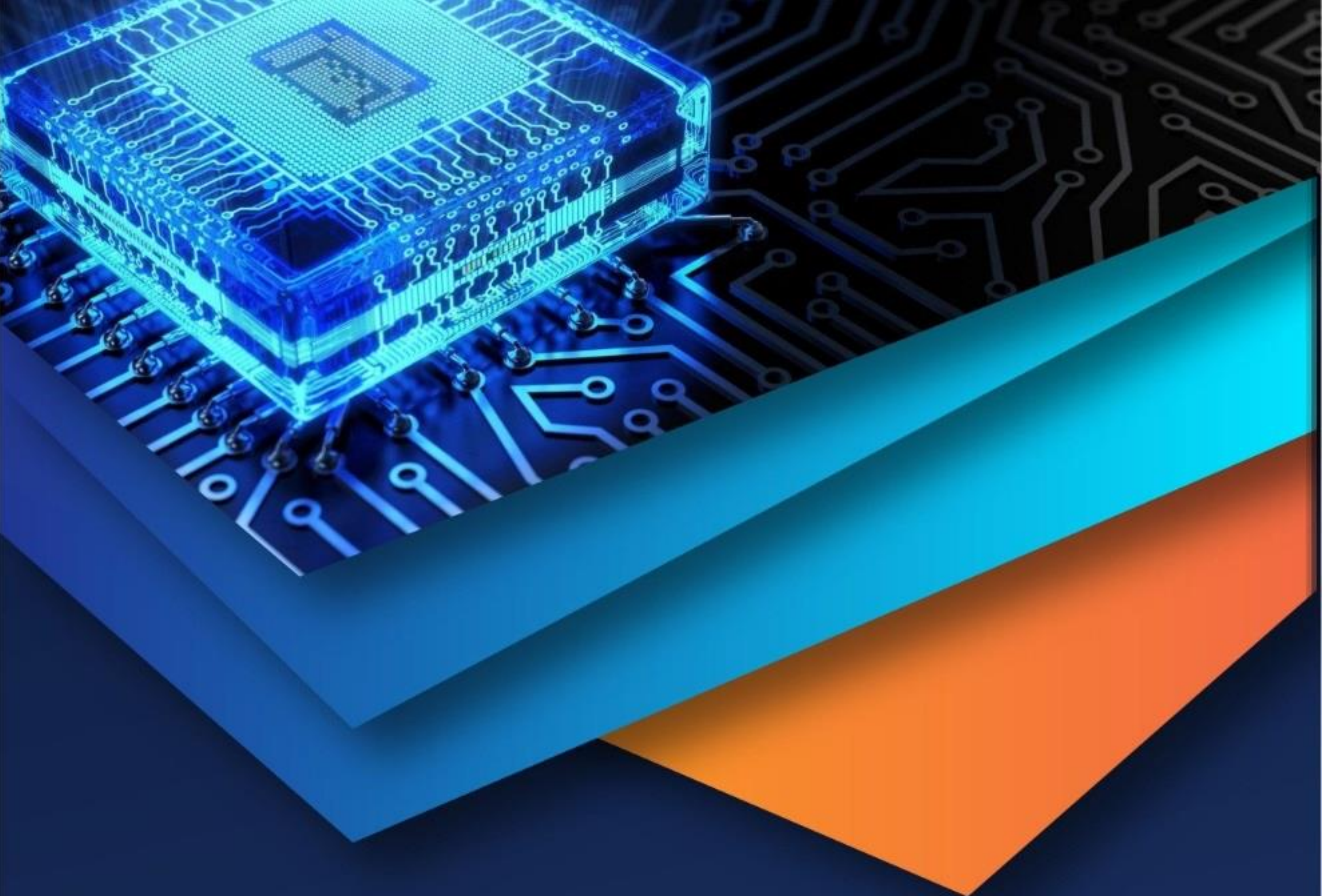

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