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OXY-HYDROGEN HYBRID DIESEL ENGINE

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ABSTRACT

Anticipating present day scenario of fossil fuels, it's foreshow that, it will endure for another few decades from now. The contrary, alarming cost of petrol/diesel fuels and its related severe effects on our ecosystem compelled the researcher to find any solution/alternate source. An alternate source is not just replacing the commercial fuel, but also increasing its fuel consumption properties. Some research were conducted, targeting on the use of oxy hydrogen gas as an additive /alternative fuel source. Although the storage of this gas necessitate the application of pure hydrogen in petrol engine. Using On-demand generation techniques for oxy-hydrogen gas (HHO) eliminates the difficulties of its storage up to a certain limit. The electrolysis process of water with KOH produces oxy-hydrogen (HHO) gas that can be used as an energy source to solve the short comings of fossil fuel reducing environmental pollution. In this study, HHO gas generator was designed, fabricated and tested experimentally to analyze its performance. The hybrid internal combustion engines using HHO is considered one of the most important studied applications. The engine performance and gas emission is investigated for a CI engines. The results recording the run time of the engine with induction of HHO gas was increased by 3240 sec to 1 liter of diesel. HHO gas reduced the exhaust gas temperature by 1^0C and also increased the idle and maximum rpm by 25 rpm and 50 rpm respectively.

Keywords: oxy-hydrogen gas, electrolysis, hybrid diesel engines.

1. INTRODUCTION

Availability of hydrogen in the atmosphere is very scarce and is commercially synthesized from hydrocarbons and also dissociation of water into its primitive states, i.e. Hydrogen and water. The fuel is highly combustible with an energy density of 121 MJ/kg (Patil *et al*., 2017, Kalyan *et al*., 2006) and does not emit harmful components into the atmosphere making Hydrogen one of the main contenders for a cleaner and environmental friendly fuel. A widely opted method to obtain Oxy-Hydrogen gas is by passing constant voltage potential across the electrode in the electrolyzed cell. Oxy-Hydrogen hybrid diesel engine is an engine which uses a mixture of oxy-hydrogen and air for its working. It mixes with diesel during combustion to produce power which drives the vehicle. It works on a normal standard diesel engine and oxy-hydrogen on demand system, produced by means of electrolysis of water. This hydrogen reacts with oxygen to form oxy-hydrogen and this gas is made to mix with air in the air intake system to achieve better combustion of fuel. Figure-1 shows the general layout of oxy hydrogen hybrid engine. Since hydrogen is highly combustible, it leads to better burning of fuel. Figures 2a, 2b and 2c depicts the energy sharing, specific energy consumption and indicated efficiency v/s H_2 flow rate respectively. This in turn increases the power, efficiency of the engine. Since the system is a hydrogen on demand system, the risks involved in the storage of hydrogen does not come into picture. Figures 3a, 3b and 3c shows the Cylinder pressure, Rate of pressure rise and Rate of heat release v/s the Crank Angle respectively for various H_2 flow rate.

Figure-1. Oxy-hydrogen hybrid diesel engine.

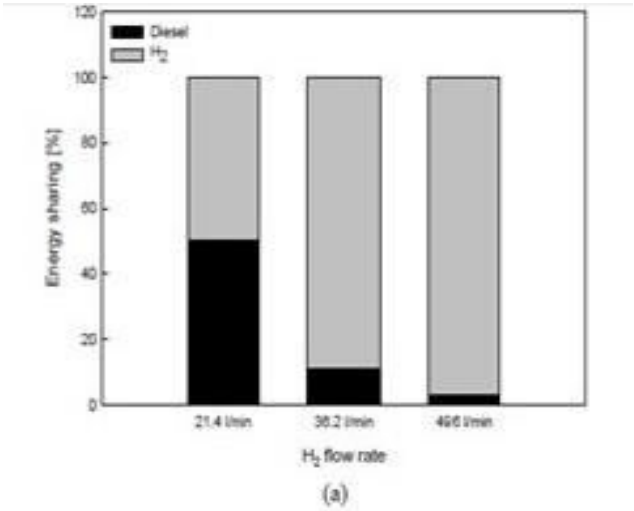


Figure-2(a). Energy sharing % v/s H_2 flow rate.

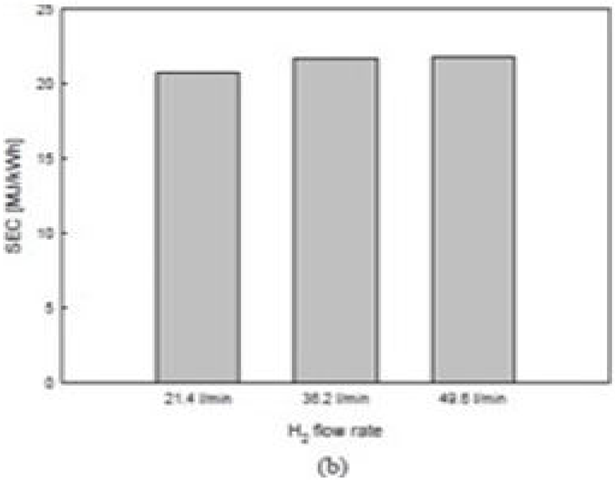


Figure-2(b). Specific energy consumption v/s H_2 flow rate.

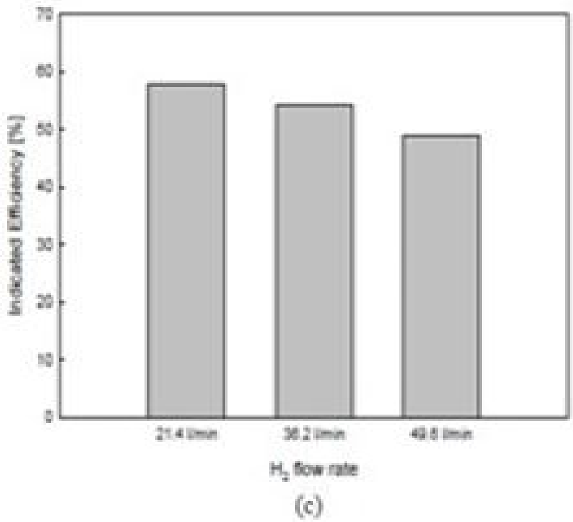


Figure-2(c). Indicated efficiency v/s H_2 flow rate.

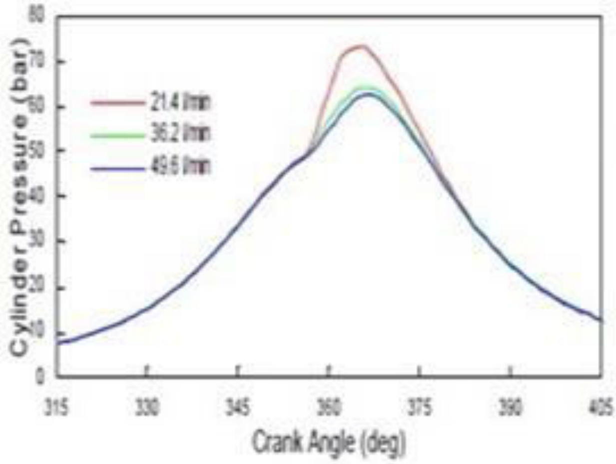


Figure-3(a). Cylinder pressure v/s crank angle for various H_2 flow rate in L/min.

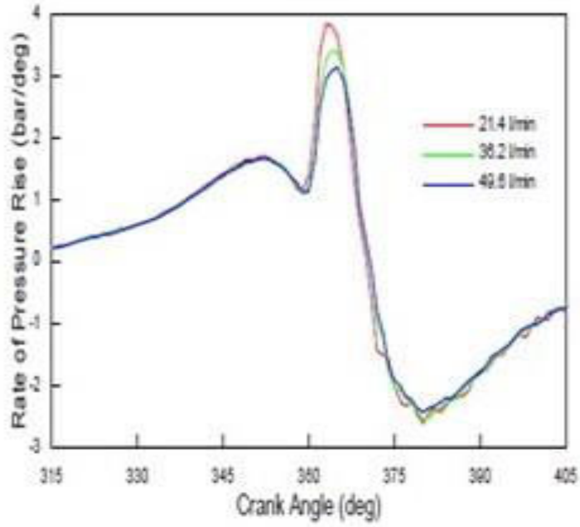


Figure-3(b). Rate of pressure rise v/s crank angle for various H_2 flow rate in L/min.

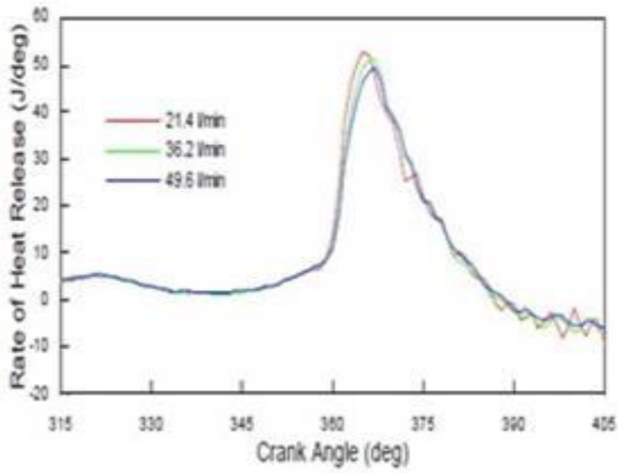


Figure-3(c). Rate of heat release v/s crank angle for various H_2 flow rate in L/min.

2. OBJECTIVES OF THE EXPERIMENT

The outcomes expected from the project are:

a) Improved fuel efficiency of the engine.

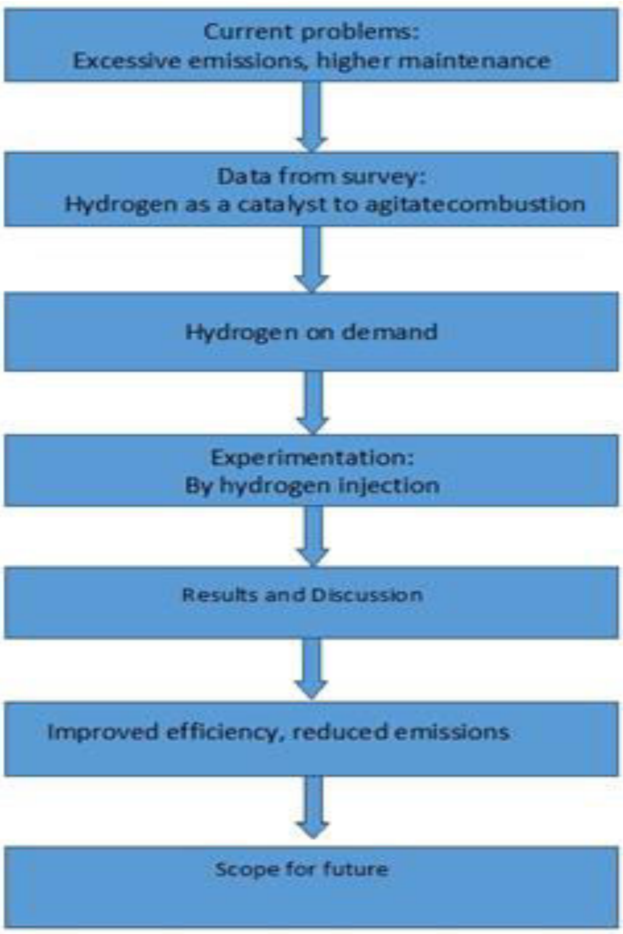
b) To reduce emissions temperature.

Increased fuel efficiency:

Since oxy-hydrogen is a very combustible gas, it accelerates the combustion of fuel in the engine. This results in the cleaner and more efficient burning of fuel this in turn increases the fuel efficiency of the engine. The increase in the fuel efficiency is claimed to be 10-30 %.

Reduced emissions:

Oxy -Hydrogen gas reduces CO to about 90%. CO is a propellant and oxy-hydrogen acts an agitator in enhancing the combustive. Oxy -Hydrogen gets rid of hydrocarbons by about 10% to 90%. Oxy- Hydrogen diminishes particulate levels, (organic particulates) by 10% ~ 70%. Oxy-hydrogen will reduce EGT (Exhaust gas temperature) from 10 to 65 ^{0} C (depending on engine load). Oxy- Hydrogen de carbonizes the engines. The fuel efficiency increased through this cleaning process generally within 7 days. In one such scenario an improvement of 12%~13% was obtained and when the hydrogen unit was removed it still retained an 10%~11% improvement (Santosoa *et al*., 2012, Pana *et al*., 2016).



3. METHODOLOGY

a) The engine is setup as per working condition, and the engine is run for various speeds.

b) The average fuel consumption, the power output, run time and emissions are noted.

c) A hydrogen fuel cell (an electrolysis unit) is fabricated using stainless steel plates,

d) Using distilled water and KOH as a catalyst electrolysis is performed, which liberates hydrogen gas. KOH is preferred over NaOH because they give off less girt and the waste water acts as a fertilizer for plants.

e) This hydrogen combines with oxygen to form oxyhydrogen gas (HHO)

f) This gas is made to enter the air intake system of the engine along with atmospheric air.

g) The engine is further tested with the hydrogen fuel cell and the various parameters are computed.

h) The variation in the above mentioned parameters is analyzed and the improvements are noted.

4. CONSTRUCTION OF THE TEST RIG

The test rig consists of two major components:

a) The single cylinder diesel engine

b) The electrolysis unit

The single cylinder diesel engine:

The engine used is an air cooled, mono cylinder, four stroke, and high speed diesel engine. Figures 4a and 4b shows the variation of power v/s rpm as per CMVR and NDIN Ratings respectively. Figures 5a and 5b shows the OEM technical specification diagram.

The technical specifications are as follows:

MODEL		**GL - 400**
Bore	mm	86
Stroke	mm	63
Capacity	cm^3	395
C.R	-	18:01
Max. torque	N-m	17
RPM	-	3600
HP NDIN 70020	-	8.5
CMVR	-	7.5
SFC	gms/bhp/hr	220

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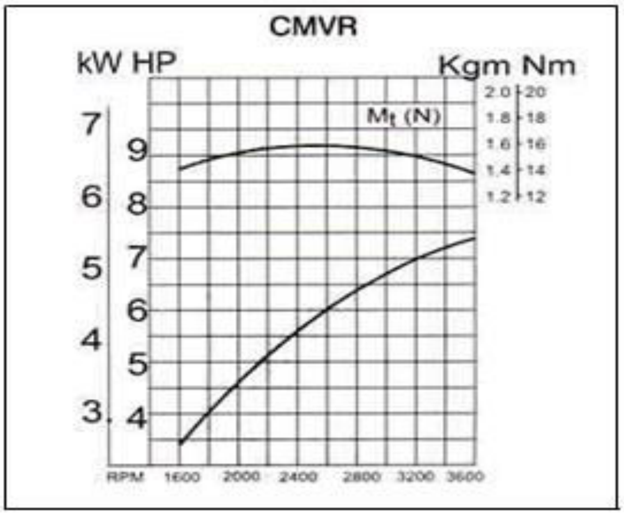

Figure-4(a). Variation of power v/s RPM as per CMVR ratings.

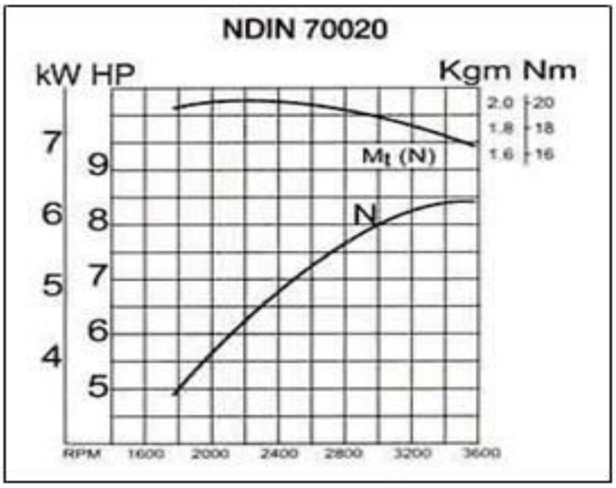

Figure-4(b). Variation of power v/s RPM as per NDIN ratings.

NDIN 70020 Automotive rating:

For intermittent duty at variable speed and variable load.

CMVR Automotive rating:

For intermittent duty at variable speed and variable load

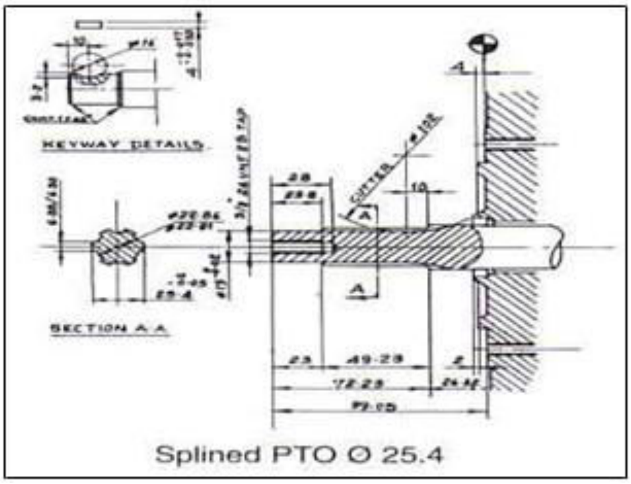

Figure-5(a). Engine specification-output shaft details.

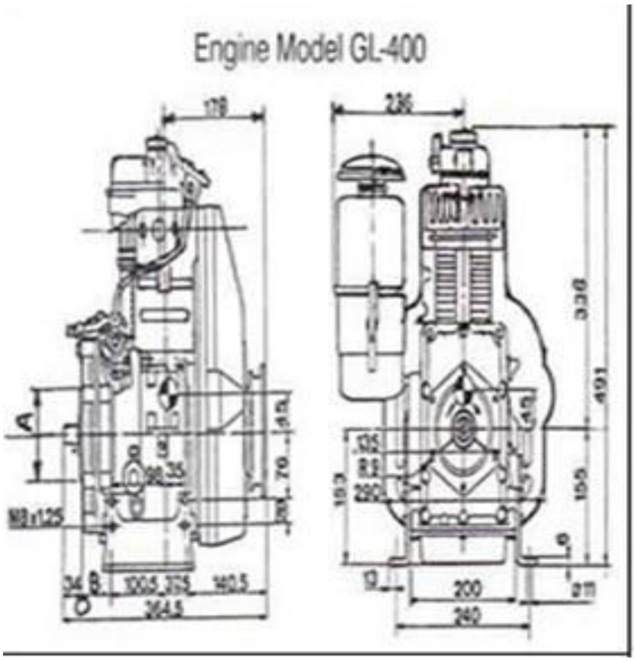

Figure-5(b). Engine specification.-front and side view.

Figure-6. Front view of the engine of test setup.

5. THE ELECTROLYSIS UNIT

Electrolysis of water is disassociated into oxygen and hydrogen due to the electric current being passed through it. The DC power when connected to two electrodes, which when placed in the water, hydrogen will get collected at the cathode and oxygen will get collected at the anode. Figure-7 is the in- house electrolysis unit.
Reduction reaction takes place with electrons (e−) from the cathode being given to hydrogen ions to form hydrogen gas.

The balanced equation with acid, is;

Reduction reaction:

$2H^+$ (aqua) + 2e− → H_2 (gas) ------------------- (1)

Oxidation reaction takes place at the anode, generating O_2 gas and giving electrons to the anode to complete the circuit:

Oxidation reaction:

$2H_2O$ (l) → O_2 (g) + $4H^+$ (aqua.) + 4e− -------- (2)

The above reaction is balanced with base. All half reactions must be balanced with acid or base, is not a compulsion.

Cathode (reduction):

2 H_2O (liquid) + 2e−→ H_2 (gas) +2OH−(aqua) --- (3)

Anode (oxidation):

4OH− (aqua.)→ O_2 (gas) + 2 H_2O (liquid) + 4 e− - - (4)

Either of the half reaction pair results in the same overall disassociation of water into oxygen and hydrogen.

Overall reaction:

2 H_2O (liquid) → 2 H_2 (gas) + O_2 (gas) --------- (5)

The hydrogen molecules produced is double that of oxygen molecules. Presuming equal temperature and pressure for both gases, hydrogen is twice in volume of oxygen.

Electrons propelled through water is double the number of hydrogen molecules and four times the number of oxygen molecules.

Theoretical Volume of H_2 liberated by the unit per unit volume of water:

2 H_2O → 2 H_2 + O_2 ------------ (6)

Molecular weight of water -18
Molecular weight of H_2 =2
Molecular weight of O_2 =32
Therefore 1mole of water=18ml=$18\times 10^{-6} m^3$

We know that, density =mass/volume ,
volume=mass/density
Therefore 1 liter of water=$10^{-3} m^3$
Hence 1 liter of water =$\frac{10^{-3}}{18*10^{-6}}$= 55.56 moles

On complete electrolysis of 1 liter of water,

i.e. (2×27.78) H_20 → 2×27.78 H_2+27.78 O_2 --(7)

Liberates 55.56 moles of hydrogen and 27.78 moles of oxygen

We know that 1mole of hydrogen=22.4 liters at STP
1 mole of oxygen =22.4 liters
Therefore
55.56 moles of hydrogen=1244.54 liters
And,
27.78 moles of oxygen=622.27 liters

Figure-7. In house electrolysis unit.

6. EXPERIMENTAL PROCEDURE

a) The test rig was constructed according to the required specifications. Fig 8 illustrates the complete test rig setup.

b) Initially the engine is allowed to freely run and under varying throttle inputs to attain optimal running conditions.

c) Then the engine is considered as a classical diesel mill and is allowed to run on diesel and atmospheric air.

d) The time taken for the engine to consume 100ml of fuel at idling RPM is noted.

e) At the same time the idling RPM is noted using a laser tachometer.

f) The test is conducted for two trails each at different times of the day to compensate for the variation in the density of air.

g) The results are computed and the efficiency of the engine is found

h) Now the same series of tests are conducted by injecting hydrogen into the air intake, the hydrogen required is produced on demand using the electrolysis unit using the power from the engines battery.

i) The values are computed at same time as the classical engine and the variations in efficiency is noted.

j) The variations at idling rpm is also noted.

k) To check the variations in the emissions a standard emission test is conducted and the variations in the pollutants is noted.

l) In the end data obtained from the test is analyzed and a conclusion is drawn.

Figure-8. Experimental set up.

7. CALCULATIONS

Run time without hydrogen addition:
Time taken for 100ml consumption=1244 sec

Run time with hydrogen addition:
Time taken for 100ml consumption =1568 sec
Increase in run time = 1568-1244 =324 sec/100ml
Increase in run time for 1 liter of diesel =3240 sec

% Decrease in emission level:
% Decrease in emission =
(Emission level without Hydrogen-Emission level with Hydrogen)/ (Emission level without Hydrogen) x 100
(46.6-46.4)/ (46.6) x 100 = 0.429%
Decrease in temperature = 72-71
= 1^{o}C

Variation in rpm:
Idle rpm without hydrogen = 1290rpm
Maximum rpm without hydrogen = 3610rpm
Idle rpm with hydrogen = 1315rpm
Maximum rpm with hydrogen = 3660
Variation in idle rpm =1315-1290= 25 rpm
Variation in maximum rpm=3660-3610=50 rpm.

8. CONCLUSIONS

a) Run time: Observations are made for checking the run time of the engine with and without the induction of oxy-hydrogen gas. Results showed an increase of 3246 sec of runtime of the engine to 1 liter of diesel.

b) Exhaust temperature: Upon induction of oxy-hydrogen gas into the CI engine, a meagre decrease of 1^{o}C of exhaust gas temperature was observed.

c) Engine idle speed: An increase of 25 rpm is achieved in the engine idling speed with the induction of oxy-hydrogen gas.

d) Maximum Engine Speed: The maximum engine speed of the CI engine has increased by 50 rpm on induction of oxy-hydrogen gas.

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