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"Optimal performance and Analysis on 4-S Si and CI Engine Fueled with HHO Gas and LPG Enriched Gasoline"

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Abstract: *An attempt has been made in this project to use alternative fuel in four stroke Gasoline engine. Our fore most aim in selecting this project is to use non-conventional fuel against conventional fuel which is becoming scarce and costly now a days. The combustion of a hydrocarbon fuel with air produces mainly carbon dioxide (CO_2) and Water (H_2O). However, internal combustion engines are not perfectly efficient, so some of the fuel is not burned, which results in the presence of hydrocarbons (HC) other organic compounds, carbon monoxide (CO) and forming mainly nitric oxide (NO).This project carried out to analyze the petrol engine exhaust pollutants, to see the effect of using LPG (liquefied petroleum gas) and HHO gasand engine exhaust gas analysis, to study the engine performance using LPG, HHO gas. Also to conduct cost benefit analysis as compared to that of pure Petrol, the mileage test with petrol, HHO gas kit, LPG gas kit.*
Keywords: *Petrol engine, Electrolysis, Oxygen Enriched hydrogen-HHO.*

I. Introduction Of Fuels

The engine derives fuel from Hydrogen gas generated by the electrolysis of water and petrol (primary fuel). Although petroleum derived fuel and an external electrical generating system is not theoretically required, in most circumstances it is a practical necessity. The only byproduct resulting from the Combustion of Hydrogen gas within the engine is water vapor. Water electrolysis is simply the breaking down of water into its basic hydrogen and oxygen atoms by passing an electronic current through it. HHO referred to as Hydrogen gas, water gas, and brown gas (in automotive applications) is a weekly bonded water molecule which exists in gaseous state. It is 2:1 molar mixtures of hydrogen and oxygen. We have to add a catalyst 9non toxic) to the water to assure electrical conductivity, as is requiredwith a battery. The water hybrid system is called a conversion system because it doesn't require removal, modification, or disabling of any of vehicles' existing systems. Therefore, it allows running the vehicle on either gasoline systems or the water hybrid system. In the unlikely event that water hybrid system fails, it can easily switch back to solely usinggasoline power. A vehicle powered by the water hybrid system is theoretically capable of traveling from 80 to 480 km on each liter of supplemental electrolyte, while improving overall fuel efficiency up to 45%.However, as is true for any engine, actual efficiency depends on many factors such as; driving habits, terrain, vehicle weight and shape, and ability to tweak and optimize the system. The water hybrid system is relatively easy to assemble and very easy to install, no special tools are required. The usual tool and equipment found in a typical home workshop will do the job.

II. Literature Survey

(1)Yull Brown developed a way to electrolyze water into HHO gas in an exact stoichiometric mix that allowed the substance to be used for welding. (2) William A. Rhodes, an American filed for international patents for a similar method of creating HHO gas that would also be used in the welding industry.(3).V. Jose Ananth Vino, Vyas Sunil Ramanlal and YemminaMadhusudhan Performance Analysis of Petrol - HHO Engine Middle-East Journal of Scientific Research 12 (12): 1737-1740, 2012, I1SSN 1990-9233, © IDOSI Publications, 2012,DOI: 10.5829/idosi.mejsr.2012.12.12.44.[4].P.T.Aravindhan, P.T.Anandhan, Efficiency Analysis of a Copper Coated SI Engine using Normal and HHOblended Gasoline under Various Loads. Volume 3,Special Issue 3, March 2014, 2014 IEEE International Conference on Innovations in Engineering and Technology (ICIET'14)[5]. Ammar A. Al-Rousan, Reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold, international journal ofhydrogen35(2010)1993.[6].Saed A. Musmar, Ammar A. A-Rousan, Effect of HHOgas on combustion emissions in gasoline engines, fuel(2011) 3066–3070

III. Introduction To Hho

Oxyhydrogen is a mixture of hydrogen (H_2) and oxygen (O_2) gases. This gaseous mixture is used for torches for the processing of refractory materials and was the first gaseous mixture used for welding. In practice a ratio of 4:1 or 5:1 hydrogen: oxygen is required to avoid an oxidizing flame. Brown's gas and HHO are fringe science synonyms for oxy hydrogen.

Fuels from Water Hydrogen Generators have become an essential fuel assistant for internal combustion engine applications**.** By converting water into its primary elements of Hydrogen and Oxygen (HHO) and introducing the hydrogen/oxygen gas in conjunction with your regular fuel, our Hydrogen Generator can improve the fuel economy of your engine from 15 - 45%+ as well as drastically lower emissions to exceptionally clean standards They can be used in any type vehicle, bike, car, truck, diesel truck, boat or stationary engine such as power generators and irrigation pumps.

HHO MOLECULE: Oxyhydrogen will combust when brought to its auto ignition temperature. For a stoichiometric mixture at normal atmospheric pressure, auto ignition occurs at about 570 °C (1065 °F). The minimum energy required to ignite such a mixture with a spark is about 20 micro joules at standard temperature and pressure, ox hydrogen can burn when it is between about 4% and 95% hydrogen by volume.

When ignited, the gas mixture releases energy and converts to water vapor, which sustains the reaction: 241.8 kJ of energy (LHV) for every mole of H_2 burned. The amount of heat energy released is independent of the mode of combustion, but the temperature of the flame varies. The maximum temperature of about 2800 °C is achieved with a pure stoichiometric mixture, about 700 degrees hotter than a hydrogen flame in air. When either of the gases is mixed in excess of this ratio, or when mixed with an inert gas like nitrogen, the heat must spread throughout a greater quantity of matter and the temperature will be low.

IV. Material Used To Make Hho Dry Cell

(1) Stainless steel 316L grade: In metallurgy, stainless steel, also known as inox steel or inox from French "inoxydable", is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass.
(2) Acrylic sheet
(3) Rubber rings
(4) P.V.C caps
(5) Stainless steel bolts & nuts
(6) Silicon pipe
(7) Distilled water mixed with KOH
(8) Inlet / Outlet valves
(9) SMPS battery

Since stainless steel resists corrosion, maintains its strength at high temperatures, and is easily maintained, it is widely used in items such as automotive and food processing products, as well as medical and health equipment. The most common US grades of stainless steel are:

Atmospheric Corrosion Resistance of Stainless Steels				
Alloy	Finish	% Stained Area	% Rusted	Pit Density (A-537)
201	CR	15	1	7
301	CR	20	3	8
302	CR	5	3	8
304	CR	3	0	8
304L	2B	15	3	9
316	CR	2	0	9
316L	2B	1	0	10
321	2B	10	5	8
347	2B	15	5	8
410	no. 2	100	80	1
430	CR	100	20	8

Table 1: Atmospheric Corrosion Resistance Of Stainless Steel

Circuit Diagram

The block diagram of the HHO dry cell consist a battery of 12 volts connected to the fuse of 20 amps. The fuse is then connected to a switch. An ammeter is kept to measure the readings of the current flowing from the battery to the HHO dry cell. The positive wire from the ammeter is connected to the HHO dry cell and the negative is connected to the car grounding. When the process starts HHO is produced and the gas from the outlet is sent directly to the carburetor with the help of a silicon pipe.

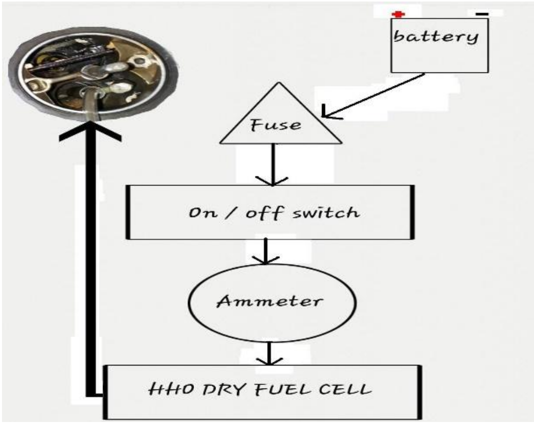


FIG 1: CIRCUIT DIAGRAM

Arrargement Of Hho Cell

Fig 2: Arrargement Of Hho Cell

V. Working Of Hho Dry Cell

When the current starts flowing through the stainless steel plate’s electrolysis process is carried out between the two terminals of the plates by which the water molecules get separated as HHO gas. The gas flows through the bubbler tank provided with a non-return valve to prevent the backpressure of gas. From bubbler the HHO gas flows through the P.V.C pipe provided at the outlet valve using the silicon pipe the gas flows to the air intake of the carburetor. Water The most abundant resource on our planet and you can use it as a fuel. That's Right, a supplementary Fuel from Water Hydrogen Generators have become an essential fuel assistant for internal combustion engine applications. By converting water into its primary elements of Hydrogen and Oxygen (HHO) and introducing the hydrogen/oxygen gas in conjunction with your regular fuel, our Hydrogen Generator can improve the fuel economy of your engine from 15 - 45%+ as well as drastically lower emissions to exceptionally clean standards . $\mathbf{2\,H_2O\,(l) \rightarrow 2\,H_2\,(g) + O_2\,(g)}$

Working Of Hho Gas In Engine

Near the air filter gets mixed up with the air and hydrogen gas coming from the hydrogen dry cell. The hydrogen gas enriches the fuel air mixture. The enriched fuel air mixture goes in the combustion chamber of the engine. As the hydrogen gas is highly flammable it helps in efficient burning of the fuel air mixture and removes the carbon deposits inside the cylinder and helps in running a cleaner engine. The process is as follows, you start with water and an electrolyte, and there are many different types. You add dc current, the H2o breaks down into H2 & O [we just call it HHO].

VI. Hho Hybrid Technology

Although the technology has been around for over a century, progress has been slow to develop an Alternative fuel from this planet's most abundant commodity known as water. With the increased dependence on fossil fuels from oil, the costs of this vital resource are escalating along with damage caused by air pollution. Global warming is a very important and real threat issue that can reduce our chances for survival in the future.

Water may just save us, if we use it wisely and keep it from becoming polluted also. The most abundant element in the known universe is hydrogen. Water is composed of two atoms of hydrogen (H) and one atom of oxygen (O).Thus H2O= Water.developed a patented pending design that is compact and can fit into almost any vehicle's motor compartment. They call it a Hybrid Cell HHO Generator. HHO is composed of two separate elements of Water, consisting of two atoms 1of Hydrogen (H) and one atom of Oxygen (O), thus H2O becomes HHO gas. The most abundant element in the known Universe is Hydrogen, which is the volatile part of this amazing fuel. Oxygen does not burn, but it does support combustion. The technology that is used to extract the two elements from water is known as Electrolysis. Electrolysis of water has been used for experimentation and other industrial processes for over a hundred years. The HHO fuel systems used today are used primarily as a supplemental fuel rather than a replacement for gasoline.

The electrolyser, a device for producing HHO, is connected to the engine's air intake plenum or duct by a hose and HHO is mixed with the air and gasoline as it is drawn into the combustion chamber. The design is considered an on demand system, meaning that HHO fuel is produced only as is needed, having no storage tank, and stopping when the ignition key is turned off. Fuel mileage is increased because the gasoline burns more completely, producing cleaner exhaust emissions, and you can save money on fuel costs and help the environment by reducing air pollution.

VII. Experimental Tests And Results

Specifications:

- ✓ Make and model "KIRLOSKER SINGLE CYLNDER DIESEL ENGINE" water cooled engine.
- ✓ Bore (D) : 80 mm
- ✓ Stroke (L) :110mm
- ✓ Speed of engine (N) :1500rpm
- ✓ Break horse power (B.H.P) : 5 H.P
- ✓ Compression ratio : 16.5:1
- ✓ Fuel : Diesel
- ✓ Specific gravity : 0.8275
- ✓ Calorific value : 10833 Kcal/Kg
- ✓ Diameter of break drum : 0.3 m
- ✓ Diameter of rope : 0.015m

Basic Equatons:

1. Brake power developed by the engine (B.P)

Brake Power = $(2\pi NTx9.81)/(60,000)$ KW

N = RPM of the Engine

T = Torque of the engine = f * r

F = Force, R = Radius

2. Mass of Fuel consumed per minute (mf):

mf = (Pipette Reading x ρ x 60)/ T x 1000 Kg/min

ρ = density of Diesel = 0.86 gm/ml

60 = Conversion from sec to min

1000 = Conversion from gm to kg

T = time taken for fuel flow

3. Total Fuel Consumption (TFC):

TFC = mf x 60 Kg/Hr

Mf = Mass of fuel

60 = Conversion from min to hr

4. Specific Fuel Consumption (SFC):

SFC = TFC/ BP Kg/KW-Hr

5. Heat Input (HI):

HI = (T.F.C) / 60 X 60) x CV in KW

CV = calorific value of Diesel = 40,000 KJ/kg

6. Brake thermal Efficiency (ηBth):

ηBth = B.P/HI x 100

7. Indicated Power (IP):

IP = (BP+FP) KW

FP = (1/3) x BP

8. Mechanical Efficiency (ηm):

ηm = BP/IP x 100

VIII. Sample Calculation For Diesel:

Observations:

1. Brake power developed by the engine (B.P)

Brake Power = (2πNTx9.81)/ (60,000) KW
N = RPM of the Engine = 1536
T = Torque of the engine = f * r = 1.035
F = Force = (F1-F2) = (8-1.1) = 6.9Kgf
R = Radius = 0.15 m
BP = (2 x π x 1536 x 9.81 x1.035) / (60000) = 1.633 KW

2. Mass of Fuel consumed per minute (mf):

mf = (Pipette Reading x ρ x 60)/ T x 1000 Kg/min
ρ = density of Diesel = 0.86 gm/ml
60 = Conversion from sec to min
1000 = Conversion from gm to kg
T = time taken for fuel flow = 48
mf = (10 x 0.86 x 60)/ 48 x 1000 = 0.01075 Kg/min

3. Total Fuel Consumption (TFC):

TFC = mf x 60 Kg/Hr
Mf = Mass of fuel = 0.01075 Kg/min
60 = Conversion from min to hr
TFC = 0.01075 x 60 = 0.645 Kg/min

4. Specific Fuel Consumption (SFC):

SFC = TFC/ BP Kg/KW-Hr
SFC = 0.645/1.633 = 0.394 Kg/KW-Hr

5. Heat Input (HI):

HI = (T.F.C) / 60 X 60) x Cv in KW
Cv = calorific value of Diesel = 40,000 KJ/kg
HI = (0.645) / (60 X 60) x 40,000 = 7.166 in KW

6. Brake thermal Efficiency (ηBth):

ηBth = B.P/HI x 100
ηBth = 1.633/7.166 x 100 = 21.19 %

7. Indicated Power (IP):

IP = (BP+FP) KW
FP = (1/3) x BP
FP = (1/3) x 1.633 = 0.544
IP = (1.633+0.544) = 2.176 KW

8. Mechanical Efficiency (ηm):

ηm = BP/IP x 100
ηm = 1.633 / 2.177 = 75.04 %

IX. Sample Calculation For Diesel + Hho:

OBSERVATIONS:

1. Brake power developed by the engine (B.P)

Brake Power = (2πNTx9.81)/ (60,000) KW
N = RPM of the Engine = 1560
T = Torque of the engine = f * r = 1.035
F = Force = (F1-F2) = (8-1.1) = 6.9Kgf
R = Radius = 0.15 m
BP = (2 x π x 1560 x 9.81 x1.035) / (60000) = 1.706 KW

2. Mass of Fuel consumed per minute (mf):

mf = (Pipette Reading x ρ x 60)/ T x 1000 Kg/min
ρ = density of Diesel = 0.86 gm/ml
60 = Conversion from sec to min
1000 = Conversion from gm to kg
T = time taken for fuel flow = 61
mf = (10 x 0.86 x 60)/ 61 x 1000 = 8.459 X 10^{-3}Kg/min

3. Total Fuel Consumption (TFC):

TFC = mf x 60 Kg/Hr
Mf = Mass of fuel = 0.01075 Kg/min

60 = Conversion from min to hr
TFC = 8.459 X 10^{-3} x 60 = 0.507 Kg/min

4. Specific Fuel Consumption (SFC):
SFC = TFC/ BP Kg/KW-Hr
SFC = 0.507/1.706 = 0.297 Kg/KW-Hr

5. Heat Input (HI):
HI = (T.F.C) / 60 X 60) x Cv in KW
Cv = calorific value of Diesel = 40,000 KJ/kg
HI = (0.507) / (60 X 60) x 40,000 = 6.055 in KW

6. Brake thermal Efficiency (ηBth):
ηBth = B.P/HI x 100
ηBth= 1.706 / 6.055 x 100 = 28.17 %

7. Indicated Power (IP):
IP = (BP+FP) KW
FP = (1/3) x BP
FP = (1/3) x 1.633 = 0.544
IP = (1.633+0.544) = 2.177 KW

8. Mechanical Efficiency (ηm):
ηm = BP/IP x 100
ηm = 1.633 / 2.177 = 75.06 %

X. Performance Tables:

❖ **Performance Test On The Engine Using Diesel:**

S.NO		1	2	3	4	5	6	7	8	9	10
Load (F)Kg	F1	0	1	2	3	4	5	6	7	8	9
	F2	0	0	0.1	0.1	0.3	0.4	0.7	0.9	1.1	1.4
Time for 10CC of fuel t (sec)		76	72	69	65	60	54	52	50	48	44
N (RPM)		1610	1580	1573	1564	1561	1559	1546	1539	1536	1532
Exhaust Temp		125	126	137	148	154	166	181	193	201	207
TFC		0.407	0.429	0.448	0.476	0.516	0.573	0.595	0.619	0.645	0.703
I.P		0	0.080	0.153	0.232	0.296	0.367	0.420	0.481	0.543	0.597
B.P		0	0.243	0.460	0.698	0.890	1.105	1.262	1.446	1.633	1.794
ηB.th		0	4.74	8.59	12.27	14.44	16.14	17.75	19.55	21.19	21.36
ηI.th		0	6.3	11.45	16.35	19.24	21.50	23.67	26.06	28.24	28.47
ηmech		0	75.23	75.04	75.05	75.04	75.06	75.02	75.03	75.04	75.03

Table.2: Performance Test On The Engine Using Diesel

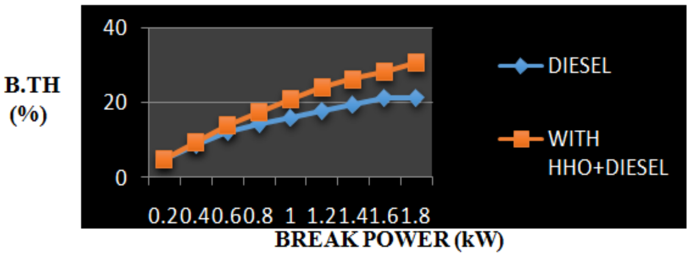
❖ **Performance Test On The Engine Using Diesel+Hho:**

S.NO		1	2	3	4	5	6	7	8	9	10
Load (F) Kg	F1	0	1	2	3	4	5	6	7	8	9
	F2	0	0	0.1	0.1	0.3	0.4	0.7	0.9	1.1	1.4
Time for 10 ml of fuel t (sec)		84	80	78	76	72	69	67	64	61	59
N (RPM)		1620	1602	1591	1580	1576	1569	1564	1561	1560	1554
Exhaust Temp		115	119	122	128	137	147	160	169	179	191
TFC		0.368	0.387	0.396	0.407	0.429	0.448	0.462	0.483	0.507	0.524
I.P		0	0.295	0.587	0.907	1.197	1.482	1.766	2.019	2.274	2.552
B.P		0	0.222	0.441	0.681	0.898	1.112	1.325	1.515	1.706	1.915
ηB.th		0	4.80	9.32	14.0	17.52	20.78	24.01	26.26	28.17	30.60
ηI.th		0	6.38	12.4	18.65	23.36	27.69	32	34.99	37.55	40.77
ηmech		0	75.25	75.12	75.08	75.06	75.08	75.04	75.05	75.07	75.06

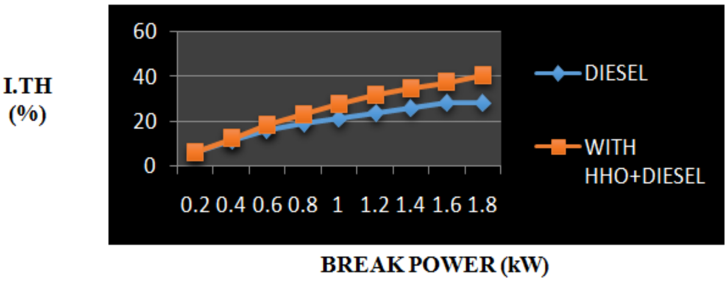
Table.3: Performance Test On The Engine Using Diesel+Hho

XI. Performance Graph

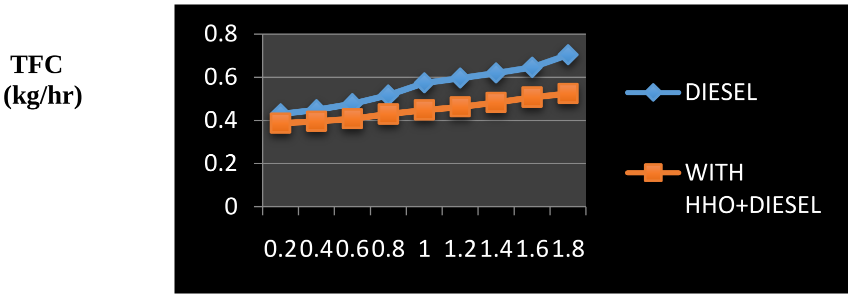
1. Graph between B.TH and B.P



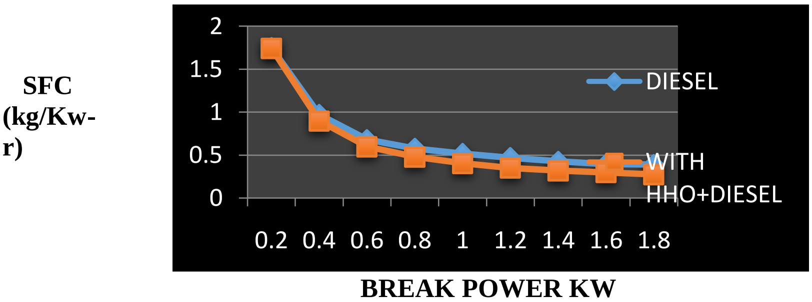
2. Graph between the I.TH and B.P



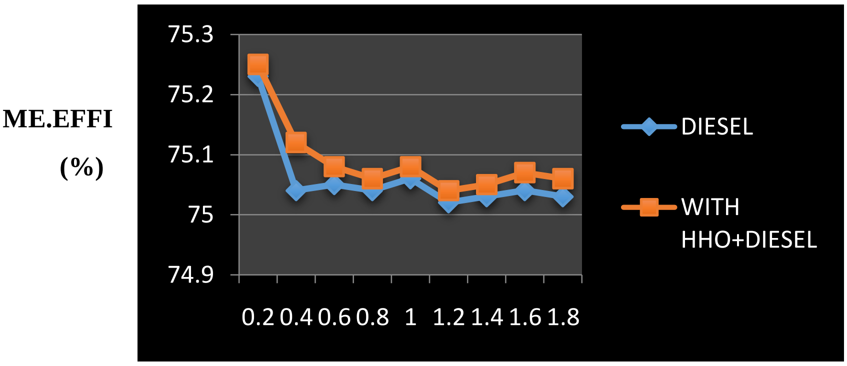
3. Graph between TFC and BP



4. Graph between SFC and BP



5. Graph between ME.EFFI and B.P



Sample Calculations:
According to our lab experiment results

FOR DIESEL for 30 ml of fuel consumption it has taken the time upto 225 secs (3:45 mins)
Then for the consumption of 100 ml it has taken the time upto 750 secs (12.5 mins)
FOR DIESEL+HHO for 30 ml of fuel consumption it has taken the time upto 240 secs (4 mins)
Then for the consumption of 100 ml it has taken the time upto 800 secs (13.3 mins)

FOR DIESEL	FOR DIESEL+HHO
For 30ml -225 secs 1ml - ? secs Then fuel consumption for 1ml is , T=225/30 =7.5 secs So the time taken for the 1ml of fuel consumption is 7.5 secs. Then for one hour how many liters of fuel is going to be consumed. 7.5*1000/3600 = 2.22 lits/hr.	For 30ml -240 secs 1ml - ? secs Then fuel consumption for 1ml is , T=240/30 =8 secs So the time taken for the 1ml of fuel consumption is 8 secs. Then for one hour how many liters of fuel is going to be consumed. 8*1000/3600 = 2.08 lits/hr.

The time taken for the saving of fuel consumption for 0.14 lits is 14*60 = 840 secs.
The fuel consumption is saved in ml is, 840/8 = 105 ml of fuel is saved. i.e. 10.5% of the fuel is saved.

XII. Result And Conclusion

Results:

1. Brake Power, indicated power, mechanical efficiency, total fuel consumption, specific fuel consumption, brake thermal efficiency and indicated thermal efficiency of the engine at various loads for diesel are measured and compared with HHO gas.
2. Performance curves are drawn at various loads and comparisons is made between pure diesel and HHO gas.
3. A comparison of fuel consumption with pure diesel and selected HHO gas is done.
4. Total fuel consumption is measured for pure diesel and HHO gases are compared.

Conclusion:

1. As the load increases brake power increases. The brake power developed by the engine operated on HHO gas is more as compared with pure diesel.
2. Brake thermal efficiency, indicated thermal efficiency, of the engine increases, for engine operated with HHO gas is more as compared with pure diesel.
3. Total fuel consumption of the engine decreases for engine operated with HHO gas is less as compared with pure diesel.
4. Mechanical efficiency of the engine increases, for engine operated with HHO gas is more as compared with pure diesel.

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