Development of electrolysis kit for internal combustion engines

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Abstract - *Transportation is the process of carrying people, raw material and finished goods from one location to desired location. Transportation has major contribution in human civilization, socio-economic, political and industrial development. An automobiles vehicle such as trucks, buses, trains, cars etc. used for transportation purpose consumes petroleum products like crude oil, petrol and diesel. Increased consumption of fuels causing air pollution and may deplete soon, so there is need to identify and produce alternative fuels which may enhance combustion efficiency as well as reduced pollution. This paper deals with the comprehensive study of different material for anode used in electrolysis kit which produces oxygen and hydrogen as alternative fuel. Further Oxy-hydrogen is passed in air petrol mixture which enhances combustion efficiency, reduces fuel consumption and controlled exhaust emission.*

Key Words: Alternative fuel, Hydrogen, electrolysis, air pollution, Combustion efficiency.

1. INTRODUCTION

According to J. Clement, India's real GDP has been at an annual rate of approximately 8 percent. As oil consumption is strongly linked to economic growth. Petroleum products are the second largest source of energy in India shares approximately 23% of total energy supply. India is the third largest oil consumer in the world [1].

The sources of petroleum and conventional energy sources are limited and by the current scenario of its usage predicts that it will deplete soon. High consumption rate of petroleum products for power production and transportation causes global warming, pollution and rise in prices and hence becomes unaffordable to most of the consumers living in developing countries.

To solve the above discussed issues there is need to discover alternative fuel which may better mileage and minimization in pollution. Electrolysis of water can produce hydrogen in form of oxy-hydrogen gas which can be used as an alternative fuel for any internal combustion engine. Addition of hydrogen can extend the lean operation limit, improve the lean burn ability and decrease burn duration.

Splitting water by electrolysis is a well-known laboratory technique. Electrolysis of water started early during first industrial revolution, when Nicholson and Carlisle were discovered the ability of electrolytic water decomposition. By 1902 more than 400 industrial water electrolysis units were in operation and in 1939 the first large water electrolysis plant with a capacity of 10,000 Nm3/h went into operation. In 1948, the first pressurized industrial electrolyser was manufactured by Zdansky/Lonza. In 1966, the first solid polymer electrolyte system (SPE) was built by General Electric, and in 1972 the first solid oxide water electrolysis unit was developed. The first advanced alkaline systems started in 1978.The history ends up in our days with the development of proton exchange membranes, usable for water electrolysis units and fuel cells, by DuPont and other manufacturers, due to the developments in the field of high temperature solid oxide technology and by the optimization and reconstruction of alkaline water electrolyser[2].

Otto, in the early 1870s, considered a variety of fuels for internal combustion engine, including hydrogen. In 1924 Ricardo conducted the first systematic engine performance tests on hydrogen at various compression ratios. At a compression ratio of 7:1, the engine achieved a peak efficiency of 43%. Several attempts have been made to the effect of using hydrogen in internal combustion engines [3, 7].

Das et al. have evaluated the potential of hydrogen for small horsepower SI engines and compared hydrogen fuelling with compressed natural gas (CNG) [3]. Another study was performed on certain drawbacks of hydrogen fuelled SI engines, such as high NO_x emission and small power output determined the performance, emission and combustion characteristics of hydrogen fuelled SI and CI engines [4]. Karim et al. has reviewed the design features and the current operational limitations associated with the hydrogen fuelled SI engine [5]. Li and Karim investigated the onset of knock in hydrogen fuelled SI engine application [6]

The paper titled, "Effect of H2/O2 addition in increasing the thermal efficiency of a diesel engine", explains the electrolysis of water and product gas was added to 4 litre diesel engine. The engine was operated under constant speed and the load. The amount of electrolysis products added to the engine was varied to determine their effect on engine efficiency and performance. Although the electrolysis unit was powered from an external power supply, the power needed to produce the electrolysis products was included as an energy input in the engine's thermal efficiency calculation. This system shows increased thermal efficiency and decrease in fuel consumption. Figure 1and 2 provides a summary of the results of this study. Figure 1 shows the effect of the addition of electrolysis products, in percentage of total diesel equivalent, on brake thermal efficiency [8].

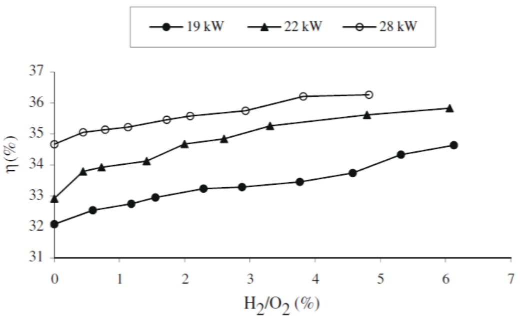

Fig -1: Variation of brake thermal efficiency with electrolysis product percentage [8].

Figure 2 shows the effect of the addition of electrolysis products, in percentage of total diesel equivalent, on percentage of fuel savings. From these figures it can be seen that, for this experimental setup, increasing the percentage of electrolysis products increased the thermal efficiency and the fuel savings [8].

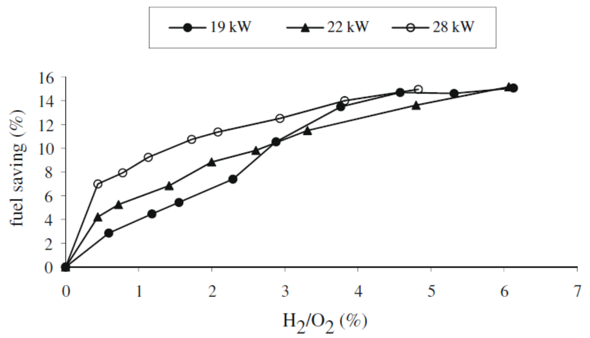

Fig -2: Variation of fuel saving with electrolysis product percentage [8].

The paper entitled, "Effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines, electrolysis products were produced by a small common-ducted electrolysis unit. This study found that the engine, combustion was enhanced by the electrolysis system and produce an average of 19.1% increase in torque compared to normal diesel operation. It was also found that an average decrease of 14% in specific fuel consumption was achieved compared to normal diesel operation.

Figure 2.3 shows the effect of the electrolysis system on engine torque over the range of engine speed.

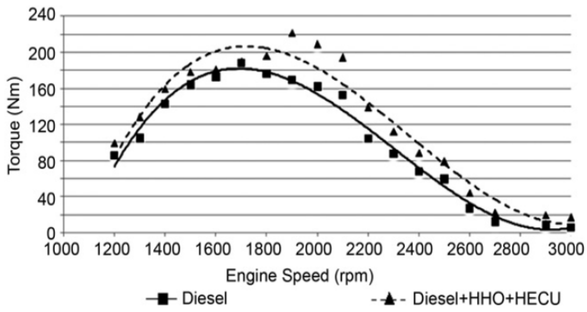

Fig -3: Variation of engine torque with engine speed [9].

Figure 4 shows the effect of the electrolysis system on specific fuel consumption. From these figures it can be seen that electrolysis system increases torque and reduce fuel consumption as compared to normal diesel operation [9].

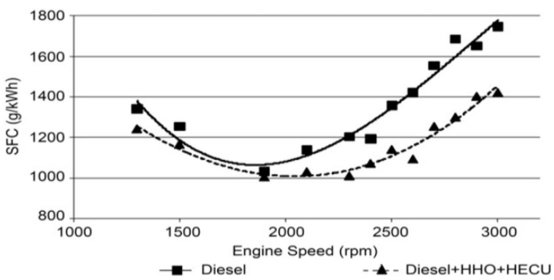

Fig -4: Specific fuel consumption [9].

Use of electrolysis system increases the fuel economy of the vehicles ranging from 26.3% to 42.9% [10]. Paper entitled "A field study of the effects of the hydrogen generating system on power, fuel economy and emissions in gasoline and diesel engines", studied and analysed the real world fuel economy data for a commercial electrolysis system. Experiments shows that fuel savings can be obtained for a wide range of vehicles. The average fuel savings, across the range of vehicles was 20.0%. [11-13].

This paper deals with the optimization of different electrode material and electrolytic solution for electrolysis of water for production of oxy-hydrogen gas, which is further blended with conventional fuel like petrol or diesel. Performance test of internal combustion engine is conducted for evaluating efficiency, mileage and exhaust emission.

2. MATERIAL SELECTION

Conventionally copper electrode is used for electrolysis of water, but the electrode reacts quickly and it degrades faster. Materials like stainless steel, graphite, platinum, MMO coated titanium etc. are considered for electrode. These materials are corrosion resistance, can handle nitric-sulphuric acids, acetic citric and lactic acids etc. and have good physical properties like good mechanical strength, weld ability, formability etc. Platinum and titanium are costlier but stainless steel is economically feasible and possesses same properties as platinum. Stainless steels of different grades viz. 302, 306, 309, 316L are used for optimization [14].

The electrolytic solution plays an important role in improving efficiency. So different electrolytes such as sodium chloride, calcium carbonate, calcium sulphate, sulphuric acid all are mixed with water and tested.

Table -1: Electrode material and its composition

Stainless steel Grade/ Composition	S-302	S-306	S-309	S-316L
Carbon (%)	0.15	0.4	0.20	0.03
Manganese (%)	2.00	0.00	0.00	0.00
Silicon (%)	0.00	0.00	0.00	0.00
Chromium (%)	7/19	8/20	2/24	6/18
Nickel (%)	.0/10	.00	2/15	0/14
Molybdenum (%)	---	---	---	.0/3.0
Phosphorus (%)	.045	.045	.045	.045
Sulphur (%)	.03	.03	.03	.03

Table -2: Properties of electrode material

Stainless steel/ Properties	SS-302	SS-306	SS-309	SS-316L
Density	8.0	8.0	8.0	8.0
Specific elec.	72	73	78	74
Specific heat	0.5	0.5	0.5	0.5
Thermal conductivity	16.3	16.3	14.2	16.3
Mild water	17.2	15.1	15.0	15.9
Abrasion resistance	Good	Good	Good	Good
Cold forming	Excellent	Good	Good	Good
Weld ability	Excellent	Good	Good	Excellent
Melting flange	1400-1420	1375-1400	1400-1450	1370 1400
Scaling temperature	900	900	1100	900
Tensile strength	90	80	90	78
Yield strength	37	31	40	30
Elongation	55	55	45	55
Rockwell hardness no	82	78	85	76
Brinell hardness no	155	149	165	145

2.1 Bill of Material

Following list of material is required for experimentation

- A sealed plastic body
- An inlet and outlet vent on body for inlet and exhaust gases
- A first terminal located at a top of the body
- A second terminal located adjacent to the first terminal
- An insulated conductor associated with each terminal extending through body, up to the base
- An anode operatively connected to one of the terminals
- A cathode associated with the other terminal
- An external source of +12V D.C supply
- Connecting wires and glue stick for sealing

3. THEORY OF ELECTROLYSIS OF WATER

The electrolysis of water produces oxygen and hydrogen gas as shown in Fig. Electrochemical cell is filled with pure water and has two electrodes connected to external power supply. At a certain value of voltage applied across voltage evolves hydrogen gas at the negatively charged electrode and oxygen gas at positively charged electrode [12].

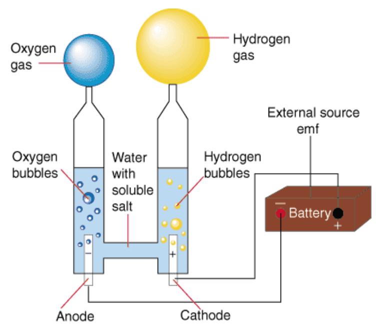

Fig -5: Experimental setup of electrolysis of water [12]

Gas is then passed to the carburettor and mixes with the air and fuel mixture. Air gas fuel mixture is further passed in to the inlet chamber of engine where it helps in complete combustion. The Air-Fuel ratio can be controlled with the help of an idling screw which may improve combustion efficiency [12].

4. FLOW CHART OF WORK

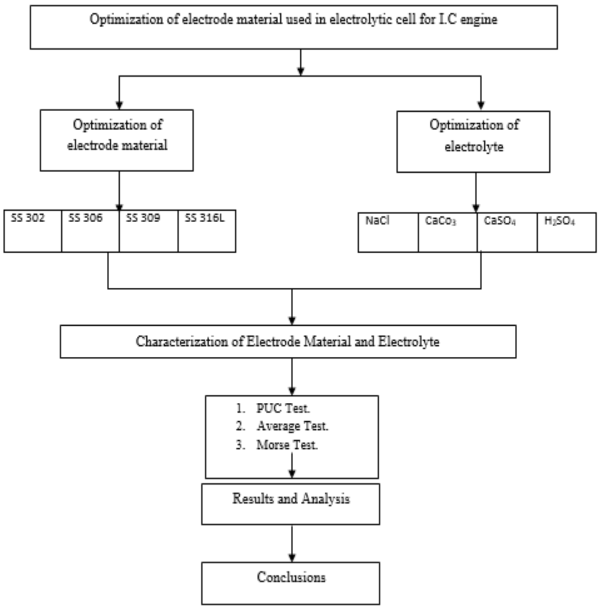

Chart-1: Flow chart of work

5. TESTING AND PERFORMANCE

5.1 Testing of Electrolyte

5.1.1 PUC test for Sodium Chloride (NaCl)

Sodium Chloride is commonly known as NaCl salt which is known to be a base in nature. A base has a pH value greater than 7. When NaCl reacts with water, it gives a chemical reaction as:

$2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$

Exhaust emission-

- Carbon Monoxide: 1.92 %
- Hydrocarbon: 1099 ppm

(HC— n- Hexane equivalent ppm)

n- Hexane: A chemical manufactured from crude oil which is an isomer of hexane. This n- Hexane is mixed with solvent for number of uses

Carbon monoxide and hydrocarbon percentage is relatively more. Inhalation of n- Hexane in large amount causes nerve damage and paralysis of arms and lungs. So NaCl is not fit for present work.

5.1.2 PUC test for Calcium Carbonate (CaCO3)

Calcium Carbonate is a salt having pH value greater than 7 and is of a basic nature. Its chemical reaction with water is as follows:

CaCO3 + H2O → Ca(OH)2 + CO2

Exhaust emission-

Carbon Monoxide: 1.99 %

Hydrocarbon: 1092 ppm

5.1.3 PUC test for Calcium Sulphate (CaSO4):

The next salt selected for the analysis is Calcium Sulphate (CaSO4) which is also a base. The chemical reaction of this salt with water is:

CaSO4 + 2H2O → H2SO4 + Ca(OH)2

Exhaust emission-

Carbon Monoxide: 2.47 %

Hydrocarbon: 2014 ppm

Carbon monoxide and hydrocarbon percentage is relatively more. So it cannot be as an electrolyte.

5.1.4 PUC test for Sulphuric Acid (H2SO4):

After trying certain number of bases, the ideology intended is to try acids and see whether they behave positively in the PUC test or completely fail in it.

So the first acid selected is Sulphuric acid which has a pH value less than 7. The reaction of Sulphuric acid with water is given as:

H2SO4 + H2O → H3O+ + HSO42-

Exhaust emission-

Carbon Monoxide: 0.03 %

Hydrocarbon: 32 ppm

Carbon monoxide and hydrocarbon percentage is relatively very much less and safe so it is best suited for defined work.

5.2 Testing of electrode material

5.2.1 SS-302

Materials for Anode: Graphite
Cathode: SS-302

Electrolyte: Concentrated Sulphuric acid (quantity 6ml with water)

Table -3: Test results for SS-302 without using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (IN CUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	2.0
2	1364	100 ml	2.0
3	1396	100 ml	1.8
4	1405	100 ml	2.2

Table -4: Test results for SS-302 using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (INCUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	3.01
2	1364	100 ml	2.9
3	1396	100 ml	2.3
4	1405	100 ml	3.2

5.2.2 SS-306

Materials for Anode: Graphite
Cathode: SS-306

Electrolyte: Concentrated Sulphuric acid (quantity 6ml with water)

Table -5: Test results for SS-306 without using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (IN CUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	2.0
2	1364	100 ml	2.0
3	1396	100 ml	1.8
4	1405	100 ml	2.2

Table -6: Test results for SS-306 using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (INCUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	2.95
2	1364	100 ml	3.1
3	1396	100 ml	2.4
4	1405	100 ml	3.25

5.2.3 SS-309

Materials for Anode: Graphite
Cathode: SS-306

Electrolyte: Concentrated Sulphuric acid (quantity 6ml with water)

Table -7: Test results for SS-309 without using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (IN CUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	2.0
2	1364	100 ml	2.0
3	1396	100 ml	1.8
4	1405	100 ml	2.2

Table -8: Test results for SS-309 using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (IN CUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	3.4 1
2	1364	100 ml	3.3
3	1396	100 ml	2.8
4	1405	100 ml	3.5 2

5.2.4 SS-316L

Materials for Anode: Graphite
Cathode: SS-316L

Electrolyte: Concentrated Sulphuric acid (quantity 6ml with water)

Table -9: Test results for SS-316L without using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (IN CUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED ({IN KILOMETERS)
1	1248	100 ml	2.0
2	1364	100 ml	2.0
3	1396	100 ml	1.8
4	1405	100 ml	2.2

Table -10: Test results for SS-316L using HHO gas

SR NO	CAPCITY OF ENGINE OF VEHICLE (IN CUBIC CENTIMETER)	CONSUMPTION OF PETROL	DISTANCE TRAVELLED (IN KILOMETERS)
1	1248	100 ml	3.38
2	1364	100 ml	3.21
3	1396	100 ml	2.62
4	1405	100 ml	3.43

5.3 Performance

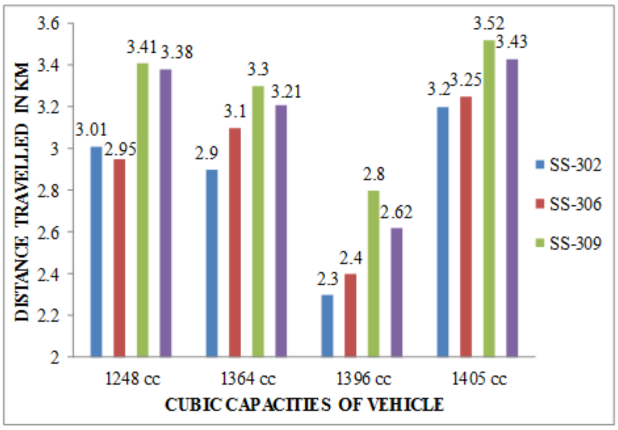

Chart-2: Comparison of distances travelled for different capacities of vehicle using various materials

Figure shows the comparative analysis of distance travelled by vehicle different capacity of engine using HHO gas produced by combination of different material for cathode and fixed electrolyte i.e. sulphuric acid. By observing chart it can be deduced that maximum distance travelled by vehicle of any capacity using HHO gas produced by combination of SS-309 as cathode material and graphite as anode. Type 309 is austenitic chromium –nickel stainless steel provides resistance to corrosion, heat, nitric and sulphuric acids. It possesses good mechanical strength at room and at elevated temperatures. It is thermally and chemically resistant and has a melting point near about 1400°C.

6. EXPERIMENTAL SETUP AND WORKING

Experimental set up consist of

6.1 Container: Container is made up of stainless steel filled with electrolyte solution. Two electrodes are immersed in it having partition in between them to avoid any mixture of gases. Diameter of container and length is 6.50cm and 10 cm respectively.

Fig -6: Container

6.2 Electrode:

There are two electrode viz. a cathode and an anode. A cathode is made up of Stainless steel of grade 309 whereas an anode is made up of Graphite. These two electrodes are connected to a battery of 12 V with the support of wires. Electrodes are 1.5 cm in diameter and 8 cm in length.

6.3 Outlet pipe:

A transparent, plastic pipe is used to transfer the resultant mixture to the air filter. Pipe is 40 cm in diameter and 0.5 cm in length.

6.4 Battery:

A 12 V lead-acid battery is connected to electrodes with wires due to which current starts flowing through the setup and the reaction is successively achieved.

6.5 Working:

The rate of reaction depends on the size and surface of electrodes. Electrolysis of water splits hydrogen and oxygen. H^+ ions move to cathode whereas the OH^- ions move to anode and further reactions takes place. The most important part of the construction of electrolysis units is to use adequate electrodes to avoid unwanted reactions, which produce impurities in the hydrogen gas. Another necessary component of such a unit is a separating membrane that allows the passage of ions, or electrons and not oxygen, or hydrogen atoms. This membrane allows the gases to be kept separate in order to avoid the risk of an explosive mixture being formed in the electrolysis unit.

7. RESULTS AND DISCUSSION

Morse test is conducted to check the engine performance. Results has been obtained as below

Table -11: Performance of engine without using HHO gas

Sr No	Fuel consumption (kg/h r)	Brake power (kW)	Specific fuel consumption (kg/kw hr)	Indicated power (kW)	Mech Effi. (%)	Break thermal effi (%)	ɳit (%)
1	0.312	0.91	0.34	1.61	56	24	43. 5

Table -12: Performance of engine using HHO gas

Sr No	Fuel consumption (kg/h r)	Brake power (kW)	Specific fuel consumption (kg/kw hr)	Indicated power (kW)	Mech Effi. (%)	Break thermal effi (%)	ɳit (%)
1	0.26	0.91	0.28 6	1.61	56.5 2	22.8	42.5

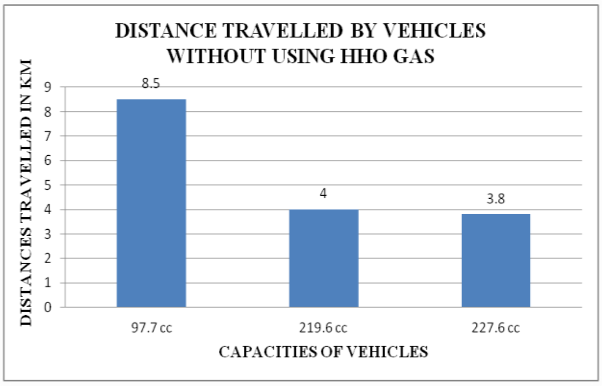

Chart-3: Distances travelled by vehicles without using HHO gas

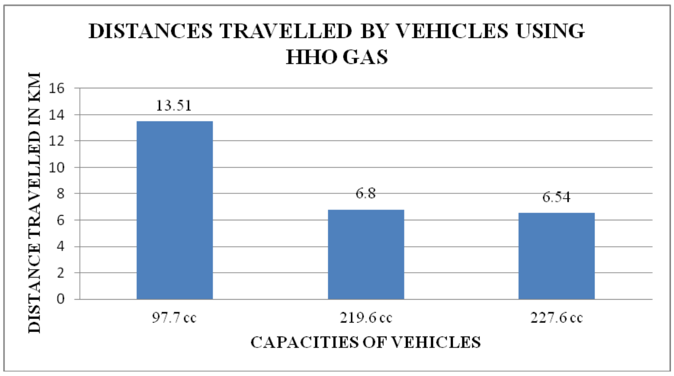

Chart-4: Distances travelled by vehicles using HHO gas

From above Chart 3 and 4, it can be deduced that distance travelled by vehicle using HHO gas is higher irrespective of capacity of engine which means engine efficiency enhanced because of introduction of HHO gas in conventional air fuel mixture.

8. CONCLUSIONS

Technology of production of HHO gas is still in research. But it can be used as supplementary fuel to improve mileage, and reduced exhaust emissions. It is proved from above investigations that hydrogen is promising eco-friendly fuel. The material considered in this work is economical as well as functioning efficiently i.e. SS-309 with H2SO4 which is thoroughly suited. This system can improve efficiency approximately 40-50%.

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