Novel Application of Electrolysis on Vehicle: Hydrogen Fuel Cell

Pavan Kumar Rejeti, Subrat Kumar Barik, and S. Balakrishna

Abstract The present world is looking for an alternate fuel source to reduce the use of conventional resources. This paper introduces a new technique to use the hydrogen produced by electrolysis used as fuel for the vehicle. The fuel is HHO gas (hydrogen and hydroxide) which is generated by electrolysis. This paper also introduces a special kind of technology, in which renewable energy sources like solar energy and H_2O are used to generate HHO gas. This fuel is having economical usefulness for our automobile industry. It will increase the efficiency of the engine and also reduce the emission to the environment. In this paper, the production rate of HHO gas which is influenced by the parameters like voltage, current, space between electrodes, time variation, and electrolyte concentration has been observed. In this research, the generation rates of wet and dry cells were also monitored.

Keywords Fuel cell · Electrolysis · Renewable energy

1 Introduction

HHO may be a well-liked and familiar gas generated within the fuel cell by the electrolysis of water. It consists of a mixture of two H_2 and O_2 gases. The basic chemical equation for conversation of water to HHO gas is $H_2O \rightarrow HHO$. The dissociation of water into hydrogen and oxygen is linked to electrolytic cells with a direct current aid. $2H_2O\ (g) + \text{Energy} \rightarrow 2H_{2\,+}\ O_2 + \text{Power}$. By using the catalyst the chemical process may easily be speeded up and the selected compound does not

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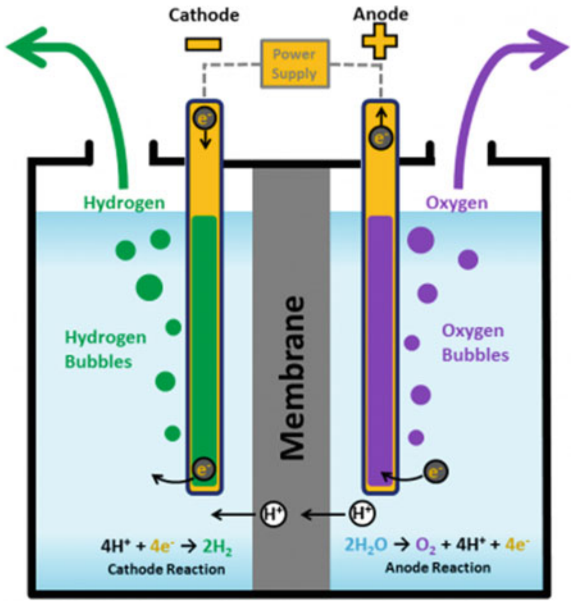

Fig. 1 Electrolysis process

change its property during the process. The main aim of the catalyst is to reduce the amount of conversion energy available. The following chemical equation describes the function of the catalyst [1, 2].

$$2H_2O + \text{CATALYST} + \text{ENERGY} \rightarrow 2H_2 + O_2 + \text{CATALYST} \quad (1)$$

As a result, electrolysis (Fig. 1):

$$2H_2O \rightarrow 2H_2 + O_2 \quad (2)$$

This is completely not harmful to nature and this does not emit carbon dioxide. This technology can be installed in all kinds of engines like cars, trucks, buses … etc. [3–5].

For HHO gas production the most principle is electrolysis in which the water splits into 2 hydrogens and 1 oxygen molecule. The hydrogen and hydrogen oxide gas is an extra boosting to the engine. Less relative molecular mass and high calorific value of HHO gas facilitate to enhance the potency of the engine. It is an extremely burnable gas and in the electrolysis method, it is the simplest for the generation. This method is clean and having less quantity of wastage and fewer emission. The speed of hydrogen is 0.098–0.197 ft/min (3–6 cm/min), the hydrogen gas is three times quicker than the other gas and oil explosion. Once a spark is generated in one end of the combustion cylinder, the gasoline is having a short period in the combustion cylinder and if it is not absolutely burnt in this time period then it simply goes out through exhaust and is lost. It is also desirable to ignite all of the gasoline when it is under maximum compression in the combustion cylinder to induce the most quantity of energy out of it. Once the piston starts moving down the energy transfer from the explosion to the engine becomes less efficient. The hydrogen's higher burn temperature and explosive force are the foremost effective output so it cleans the soot that gathers within the engine (its like maintaining the engine uniformly) and you can achieve better mileage and less oil changes with a cleaner engine [6–8].

Using deep sub Debye length gap electrochemical cell, electrolyte free pure water electrolysis has been achieved when the gap between cathode and anode is even smaller than the length of electrical molecule motion, the double layer region of two electrodes will overlap with each other, resulting in a uniformly high electrical field distributed within the line gap. Such a strong electric field will greatly boost the transport of ions within the water, increase water self-ionization further and sustain the continuation of the total reaction and display little resistance between two electrodes [9–11].

So we are making a complete setup where HHO gas is used as fuel which is produced by the electrolysis process. Water is acting as secondary indirect fuel because from there only HHO gas is produced. Hence use of HHO gas is not only effective but also eco-friendly.

1.1 Effect of Emission to the Environment of HHO Gas

Adding HHO to an internal combustion engine leads to a quicker, additional combustion of the present fuel. Quicker and additional thorough combustion means additional energy is transferred mechanically to the engine, rather than wasted heat through the exhaust. This incorporates a positive impact not solely on power and fuel economy however conjointly on emissions [12, 13]. The quicker flame propagation speed of hydrogen is answerable for this and is commonly compared to a large "spark plug" within the engine that ignites all the flammable fuel. In summary, vehicle emissions are commonly comprised of five gases (the sixth applies to diesel-fuelled engines) [14, 15],

- HC
- NOX
- O_2
- CO
- CO_2

The elements of these are coming out of HHO gas can be reduced to maximum extend by different processes.

2 Methods of HHO Generation (Fuel Cells)

Generally, the HHO fuel cells are prepared in different ways. This electrolysis process is carried out in two ways those are HHO Wet fuel cell and HHO Dry fuel cell.

In this process, we have considered stainless steel as an electrode material because its having high corrosive resistance and good conductivity and also most important factor is the cost of material is less compared to other material like copper, aluminum, etc. [11, 12].

2.1 Preparation of HHO Wet Fuel Cell

Hydrogen and hydroxide gas will generate by the electrolysis process in this process the different elements are used they are described below.

1. Stainless steel plates
2. Glass container
3. Plastic strips
4. Bubbler

2.1.1 Experimental Procedure

The eight electrolysis plates are about 0.8 mm thick and 160 mm × 200 mm stainless steel. A 10 mm gas vent hole is drilled in each plate as shown in Fig. 2. The level of the electrolyte is always about 25 mm below the vent hole of the leg. In the bottom corner of each plate, 3 mm dia, liquid level equalization holes are drilled in such a way as efficiency loss due to current leakage between cells, but makes electrolyte filling and level equalization much simpler. A tiny SS component is welded to the two end plates for electrical contact, the arrangement of steel plates is like electrode which cathode, and anode and these plates having some of the electrode gap 2–3 mm gap, in this gap will be maintained at constant. The electrode cell will dip in the container and passing the electricity through the electrode then the H_2O will split into hydrogen and hydrogen oxide. In this cell, the production rate is very low compared to the dry cell and the construction of the wet cell as the following diagram.

2.2 Preparation of HHO Dry Cell

Hydrogen and hydroxide gas will generate by the electrolysis process. In this process, the different elements are used those are stainless steel plates with grade 316 L and battery of 12 V 5 A and hoses and electrical cables and fiber plates, ammeter and voltmeter and rheostat which are connected as per circuit diagram. The dry cell can

Fig. 2 Experimental set up

be operated on electrolysis. The electricity is passing through the electrodes then the hydroxide is generating on anode and hydrogen is generating on cathode then finally we will get a new form of gas HHO.

In preparation of dry cell first of all the stainless steel is made electrodes as per dimensions, the shape the electrode is an octagon shape. Its side length is 30 mm and the radius is 55 mm. According to the number of plates the production rate will be dependent, because the area of contact is increasing then increasing the production rate of HHO gas The stainless steel electrodes are chosen as its material composition relatively insert properly in alkaline solution in which the electrodes can be drilled by drilling machine the hole size is diameter 10 mm and each plate having two holes, on a hole is water flow and another hole is flowing of gas in this dry cell, total number of plates are 21 plates are used in 5 plates required to electricity by using D.C battery is arranged in an alternative manner in the cathode and another one is the anode. Then arrange these electrodes while the gap will be kept constant that is 2–3 mm. This gap will be covered with O-rings. Finally, a dry cell can be arranged by using nut and bolts, before arranging the cell, both sides are covered with fiber plates. It helps to control the leakage of water, and both ends can be arranged with nozzles by passing water and HHO gas for removing saturation of gas by using a muffler (Fig. 3).

Fig. 3 Dry cell

2.3 Flow Chart of Cyclic Process of HHO Generation

The process is carried out with the generation of HHO by renewable energy sources like solar energy and water; those are utilizing cyclically. The connections are developing as following block diagram. This block diagram shows clearly the process of generation of HHO gas, the sun energy focusing on the solar panel in which the intensity of energy is converted into electrical energy by using the charging unit it is connected to the battery it stores the DC electrical energy. Then the DC supply is connected to electrode cell, one is connected with positive terminal and another one is connected with negative terminal and finally, HHO gas will be generated it will supply to intake manifold it's construction will be following in block diagram. And at a time fuel and brown gas will supply to the engine in the combustion chamber it will burn at maximum power developing in the engine, because of the HHO gas atomic weight is very less so it is having high calorific value so it will burn 2–3 times faster than the gas oil (petrol). In the flow diagram finally the maximum output will be developing, the crankshaft will be connecting with a crank which is rotating at high speed, this crank will be connecting with a sprocket this is attached to the back wheel hub of the bicycle with proper alignment then finally the power can transmission to rear wheels (Fig. 4).

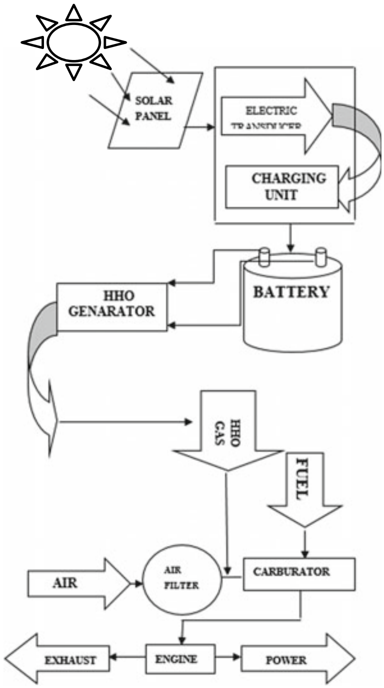

Fig. 4 Flow chart of the cyclic process of HHO generation

3 Testing and Results

3.1 Experimental Calculations

The experimental calculations have been carried out by two steps with room temperature and taking 1 atm pressure.

1. Half-reactions take place at the anode and the cathode.

$$H_2O \rightarrow 2H + O_2$$

$$2H + 2e^- \rightarrow H_2$$

$$2O^- \rightarrow O2 + 4e^-$$

2. Calculation of the number of moles of electrons that are transferred.

- Ampere × Time = Columbus
- 1 F = 96,485 Columbus
- 1 F = 1 mol of electron

The following are the calculations that have been made to see the amount of hydrogen and oxygen gas is produced inside the final prototype HHO generator over an hour. The electric current is the driving factor in this calculation considering the motorized bicycle alternator is sending an average of 90 amps to the generator.

$$90\,\text{A} \times 3600\,\text{s} = 32,4000\,\text{columbus}$$

$$32,4000\,\text{coulmbus} \times \frac{1\,\text{faraday}}{96485\,\text{colum}} = 3.3580\,\text{faraday}$$

$$3.3580\,\text{faraday} \times \frac{1\,\text{mole electron}}{1\,\text{faraday}} = 3.3580\,\text{faraday}$$

From the stoichiometry taken from the balanced half-reactions, we obtain the moles of hydrogen and oxygen produced.

$$3.3580\text{ mole e}^- \times \frac{1\text{ mole H}_2}{2\text{mole e}^-} = 1.679\text{ mole H}_2$$

$$3.3580\text{ mole e}^- \times \frac{1\text{ mole Oxygen}}{4\text{ moles of e}^-} = 0.8395\text{ mole O}_2$$

Using the ideal gas equation ***PV = n RT*** we get the value of the volume of each gas

$$V = n\,RT/P$$

where
n = number of moles
R = Boltzmann constant = 0.08206
T = Temperature in Kelvin = 300 K

- The volume of hydrogen gas:
  $\frac{1.169\text{ mole H}_2 \times 0.08206\,\text{L atm/mole K} \times 298}{1\text{ atm}} = 41.05\,\text{L of H}_2.$
  The volume of oxygen gas:

$$\frac{0.8395\text{ mole O}_2 \times 0.08206\text{ L atm/mole K} \times 298}{1\text{ atm}} = 20.529\,\text{L of O}_2$$

These calculations have shown that for a current of 90 A during 1 h, the calculations of electrolysis of water yield 41.05 L of hydrogen gas and 20.529 L of oxygen gas.

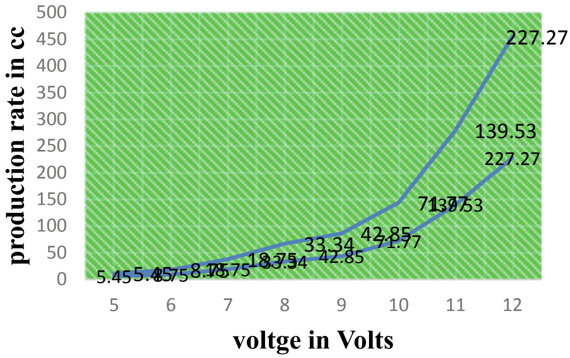

Fig. 5 Effect of production rate with change voltage

3.2 *Effect of Production Rate with Change Voltage*

The production of hydroxyl is influenced by the applied voltage. With a 0.1 mol concentration of KOH, the hydrogen evolution reaction and oxygen evolution reaction can be examined over a flat plate stainless steel electrode at room temp. of 27 °C. The applied voltage ranges from 5 to 12 V and the resulting graphs shows that the rate of output of hydrogen gas rises steadily with increased applied voltage. The likely explanation is that the uniform charge density increases on the flat plate electrode surface (Fig. 5).

3.3 *Effect of Production Rate with Change Current*

The production of hydroxyl is influenced by the applied current. With the same condition taken before the resultant graph as shown below shows that the rate of production of hydrogen gas gradually increases with the increase in applied current. The reason is the uniform charge density increases on the surface of the flat plate electrode. As shown in the Fig. 6 the production rate also depends on the current. At constant voltage, as current increases gas production rate also increases the production rate of HHO gas varying of the production rate with constant voltage remaining

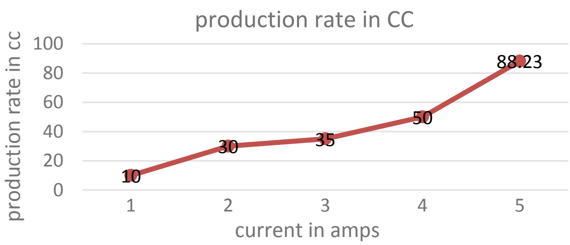

Fig. 6 Effect of production rate with change current

Table 1 Effect of production rate with change current

Current (A)	Production rate (cc)
1	10
2	30
3	35
4	50
5	88.23

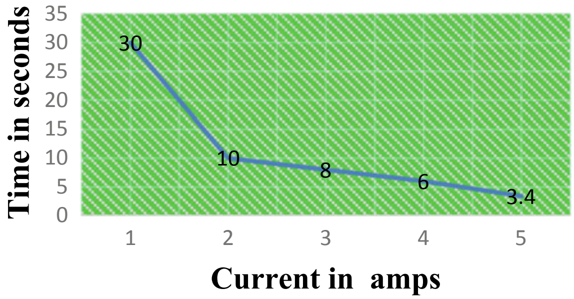

Fig. 7 Current with a graph time variation

constant at 12 V, the experimental values are taken by generation rate of HHO gas (Table 1).

3.4 Effect of Time on Production Rate

Analysis of the continuous output of hydroxyl gas for flat plate electrodes with a continuous increase in electrolysis time is very interesting. The rate of output of hydroxyl gas increases steadily at the beginning of electrolysis and becomes maximum within 5 min. After that, very little variation in the rate of gas output fluctuates. The results obtained are illustrated in Fig. 7. It is observed that the output of hydroxyl gas is initially reached to a maximum of 200 cc/min and thus achieves a stable state. Under current experimental conditions, the overall output of the stainless steel electrode has shown a reasonable degree of stability by performing the experimental procedure then obtaining the following values, the time variance at constant voltage with the variation of current with time changes.

3.5 Current and Voltage with Time Variation

See Figs. 7 and 8.

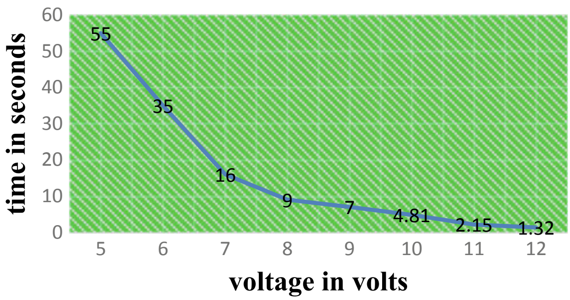

Fig. 8 Voltage with time variation graph

Table 2 Effect of electric concentration

S. No	Amount of fuel consumption	Distance covered
1	50 ml	1.218 km
2	100 ml	2.436 km
3	150 ml	3.412 km

3.6 Effect of Electrolyte Concentration

The concentration of the electrolyte is carried by constant voltage 12 V battery and 3 A current is adjusted by the rheostat connected parallel to the load and the digital multimeter connected in series to the electrolyte at constant current. In this system, the concentration of the electrolyte is an increase from 0.1 to 2 mol concentration in rainwater, the catalyst increases the ionic conductivity of rainwater increases. In pure water, no electrons flow into that water, so with the increased conductivity of rainwater, the resistance of the overall electrolyte system is reduced thus reduces the effect of the over voltages value on electrode load. The acidic and alkali solution used to be limited and by the practical applications, it will be affected by corrosion of the electrode surface, the hydroxyl gas production gradually increases with increasing the electrolyte concentration (Table 2).

3.7 Analysis of Wet and Dry Cell

The analysis of wet and dry cells have concluded that the main difference in production rate in the wet cell production rate is low compared to the dry cell, the production rate of these cells at varying time are discussed as in Fig. 9.

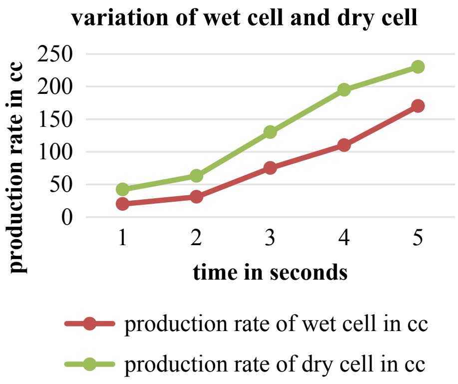

Fig. 9 Analysis of dry and wet cell

3.8 Analysis of Mileage with and Without Brown Gas

Total distance covered without brown gas is = 7.066 km

Total distance covered with using brown gas is = 13.385 km

$$\text{Percentage of increasing efficiency} = \frac{13.385 - 7.066}{7.066} \times 100 = 85.9\%$$

From the above data considering the mileage of vehicle increasing with 80–90% with the engine mixing of fuel and brown gas, and also some of the modifications to consider the above design modification takes place in the system to increase the efficiency of the engine (Tables 3 and 4).

Table 3 Mileage without brown gas

Time (s)	Wet cell production rate in cc	Dry cell production rate in CC
5	20	42
10	31	63
15	75	130
20	110	195
25	170	230

Table 4 Effect of production rate with change current

S. No.	Amount of fuel consumption with brown gas	Distance covered
1	50 ml	2.150 km
2	100 ml	4.715 km
3	150 ml	6.515 km

4 Conclusion

The cylinder pressure is increased once combining with HHO and the amount of flame development and fast combustion was shortened. With the rise in HHO content, the cyclic variations were reduced, combustion stability is improved. Partial burning and alternative abnormal combustion phenomena are controlled. The generated gas is mixed with fresh air simply before getting into the mechanical device. The exhaust is sampled by a gas analyzer and therefore the exhaust constituents and their concentrations are evaluated. Therefore the subsequent conclusions may be drawn.

- HHO cell can be simply integrated with existing engine systems
- The combustion potency has been increased once HHO gas has been introduced to the air/fuel mixture, consequently reducing fuel consumption.
- The concentration of oxide has been reduced to fifty percent.
- The typical concentration of carbon monoxide gas has been reduced to twenty percent.
- The nitrogen oxide concentration is reduced about fifty four percentage.

Brown' gas (HHO) has recently been introduced to the motorcar business as a replacement supply of energy. The current work proposes the look of a replacement device connected to the engine to integrate associate HHO production system with the internal combustion engine. The planned HHO generating device is compact and might be put in within the engine compartment. The auxillary device was designed, made, integrated and tested on an IC engine.

The research shows a positive aspect of the use of HHO gas as an alternative fuel. From the last years, scientists are inventing so many renewal sources which will replace the use of petrol and diesel. Here we have tried the same thing but differently. Previously hydrogen gas is stored in the tank from outside and being used as fuel for vehicles. Here we have attached the setup to the vehicle so that both generation of HHO gas and its use in the engine can be obtained. Various practical tests conformed about the increment in the acceleration of the vehicle. It helps economically for the present and future generation, for reducing the utilization of petrol and diesel, now HHO gas generated by renewable energy sources like H_2O with help of electricity, in future other researches can avail to get it from different sources. It is not only eco-friendly but also helps in increasing in the life of engine oil more than 2–3 times than normal one and also shows the variation in the mileage of 2 stroke petrol engine with brown gas and without brown gas, that is reducing the consumption of petrol is less up to 60–70% and also reducing the emission to the environment up to 0.2 ppm (parts per million). The generation of HHO gas by dry cells compared to the wet cell method is increasing the production rate up to 50–60%. The HHO is compatible with all bikes and scooters below 1000 cc. Further research will glow the hidden side of this method.

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