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Research article

Conversion of Natural Gas to Energy through Pemfc to Apply at Commercial Application

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Abstract

Due to depletion of fuel and the scarcity of crude in upcoming years, inclination towards alternative energy sources lead us to think for an alternative to the existing fuels' replacement. Also as many industrial processes, combustion processes release excess amount of natural gas. This amount of natural gas is burned off or flared in the atmosphere. Much of such gas is being wasted which worth billions of dollars. Hence

Natural gas can be utilized for the energy production and alternative to fuels' for automobile Industries. To fulfil this objective, the scope of the study targets the following project execution at application level. Separation of Hydrogen from Natural Gas, synthesis of Polymeric membrane, assemble the Polymeric electrolytic material Fuel Cell (PEMFC) for Electricity generation, assemble the Polymeric electrolytic material Fuel Cell (PEMFC) for Electricity generation, energy production trials and engine performance with Natural gas as a fuel.

Keywords: PEMFC; Proton Exchange Membrane Fuel Cell; Natural Gas; Alternative Energy Source

Introduction

Now-a-days most of the researchers are focusing on green energy to save this world's future from hazardous chemical and substances. To do that, they can either find out or invent energy source or modify the current process with the better solution which could be less harmful to the environment of globe. From this perception, oil and gas and automobile sectors are one of the focusing sectors to implement for the better world. Starting with the oil and gas sector, the most common issue which should be addressed is the burning of wasted and unused natural gas in the environment which generates methane in high amount, carbon dioxide and other gases. In addition, methane is the principal source of energy in many sectors. However, more than 31% of natural gas is directly burned off to the environment in Bakken since 2010 because of no use and its value is estimated to be around $1.4 billion and in adding to this, more than 150 billion cubic meter of natural gas get burned off annually in the entire globe [1]. Basically, this situation is the major loss for the world and energy sectors and this natural gas should utilize in a proper way. With the view of this, natural gas can be utilized to generate electricity with the help of fuel cell.

There are various types of fuel cells available to generate electricity from natural gas of which 2 types are mainly PEMFC (Proton Exchange Membrane Fuel Cell) and SOFC (Solid Oxide Fuel Cell). To generate electricity from these 2 fuel cells, natural gas should be converted into the hydrogen. Therefore, steam reforming process can be used for the conversion and the produced hydrogen can be utilized for electricity generation without affecting environment. However, the operating temperature and pressure is higher to produce electricity and inlet of syngas ($H2 + CO$) is not easy to handle. While, about PEMFC, the operating temperature and pressure is preferable for lab experiments. Therefore, PEMFC is suitable for easy operation and also operating of hydrogen gas as inlet is quite difficult as MCFC. So, in this study we have used PEMFC for the experiments. However, in our study, the steam reforming process is considered theoretically only and experiments were performed as an inlet of hydrogen and oxygen gases in the PEMFC.

According to this trend, many automobile industries are using this concept to build a car for the future which could run on fuel cell and hydrogen gas. They are suggesting that this type of car is environment friendly because it emits 0% carbon dioxide and carbon monoxide to the atmosphere. As per European Environment Agency (EPA), car plays a major role for the emission of carbon dioxide by burning fuel such petrol and diesel which is about 67% share in all vehicle types. Therefore,

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making a environment friendly car is the better solution to reduce emission of greenhouse gases.

This study was executed in light of the above discussions and is focused on providing a better solution for the usage natural gas by considering hydrogen gas for the experiment. We did several experiments with differences in parameters such as flow rate and flow pattern. To get results, we used ammeter and voltmeter to measure current density and power. Based on those results, we have plotted graphs according to parameters and best solution for PEMFC size of 5×5 cm (25 cm2 active surface area) is also suggested at the end.

Experimental

In this study, we have used Proton Exchange Membrane Fuel Cell (PEMFC) with the size of 5×5 cm along with the active surface area of 25 cm^2. Apart from that, two tire tube we also have used to store hydrogen and oxygen gas for the reaction into the PEMFC. In addition, the list of all apparatus has been given after the experiment setup.

Moving towards experimental details, first of all, the cylinders of hydrogen and oxygen gases has been installed nearer to the experimental setup. Then, two tire tubes have been filled by hydrogen and oxygen gases respectively. The option to use tire tubes for storage of gases is because of risk factor of gas cylinder. The hydrogen gas is stored at extremely high pressure in the cylinder. Therefore, it can damage or penetrate the membrane of the fuel cell. So, to avoid damage and for safety reason we gave flow to PEMFC by tire tubes. To maintain flow rate or take parameters for the experiment we gave pressure on the tubes to execute.

To get optimal possible flow pattern and parameters we have done several experiments on different flow rate, pressure and flow patterns. We took 3 flow patterns such as CoCurrent, Counter Current and Cross Flow pattern.

Here, the total assembly of PEMFC with the help of Figure 1 and Figure 2 as shown below.

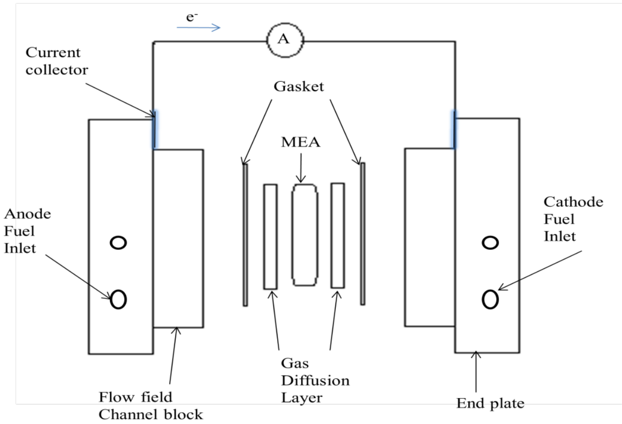

Figure 1: Schematic setup of PEMFC.

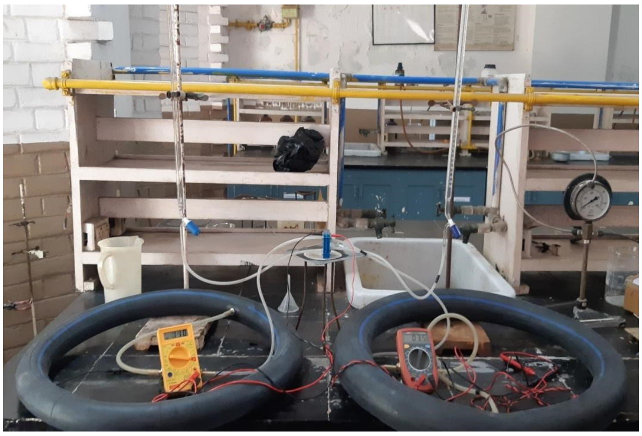

Figure 2: Experimental setup at lab level

These are the components which we use in our experiment.

- Burette with stand – 2 Nos.
- PEMFC
- Silicon tube
- Tire tube – 2 Nos.
- Hydrogen and Oxygen gas cylinder
- Multimeter – 2 Nos.
- Soap solution
- Flow controller
- Pressure gauge
- Wire
- Stopwatch

Based on our observation we have illustrated only 3 conditions. In detail, 3 different ratios of Hydrogen (H2) : Oxygen (O2) are 1:2 (Counter Current Flow), 2:1 (Counter Current Flow) and 1:1 (Cross Flow).

Experimental data

Flow rate of Hydrogen gas = 5 ml/sec , Flow rate of Oxygen gas =10 ml/sec (Counter Current flow pattern) (Table 1).

Table 1: Experimental data of 1:2 flow rate (Counter Current).

Sr. No	Time (Second)	Current (mA)	Voltage (mV)	Power (μW)
1	60	22.3	101	2252.3
2	120	51.4	280	14392
3	180	86.4	470	40608
4	240	89.9	579	52052.1
5	300	99.5	568	56516
6	360	97.1	614	59619.4
7	420	101.1	613	61974.3
8	480	95.3	569	54225.7

9	540	99.6	582	57967.2
10	600	98.1	587	57584.7
11	660	91.6	610	55876
12	720	94.4	578	54563.2

Flow rate of Hydrogen gas = 10 ml/sec , Flow rate of Oxygen gas =5 ml/sec (Counter Current flow pattern)

Table 2: Experimental data of 2:1 flow rate (Counter Current)

Sr. No	Time (Second)	Current (mA)	Voltage (mV)	Power (μW)
1.	60	7.2	29	208.8
2.	120	124.9	623	77812.7
3.	180	119.2	716	85347.2
4.	240	122.1	696	84981.6
5.	300	120.6	678	81766.8
6.	360	114.2	748	85421.6
7.	420	113.3	739	83728.7
8.	480	112.2	731	82018.2
9.	540	112.1	729	81720.9
10.	600	109.7	718	78764.6
11.	660	109.1	718	78333.8
12.	720	109	719	78371

Flow rate of Hydrogen gas = 5 ml/sec , Flow rate of Oxygen gas =5 ml/sec (Cross Flow pattern)

Table 3: Experimental data of 1:1 flow rate (Cross Flow)

Sr. No	Time (Second)	Current (mA)	Voltage (mV)	Power (μW)
1.	60	33.1	101	3343.1
2.	120	89.9	896	80550.4
3.	180	96.7	926	89544.2
4.	240	101.5	927	94090.5
5.	300	98.5	855	84217.5
6.	360	102.3	930	95139
7.	420	105.1	929	97637.9
8.	480	106.3	915	97264.5
9.	540	101.9	925	94257.5
10.	600	105.1	930	97743
11.	660	100.6	926	93155.6
12.	720	105.8	923	97653.4

Result and Discussion

As per several parameters, we have shortened out 3 optimal parameters for 5×5 cm of PEMFC. Firstly, we tried Co-current pattern to get result of power, but there is no readings in ammeter and voltmeter. Therefore, co-current pattern is not suitable for the power generation. Then we tried counter current and cross flow pattern. We have seen that Counter Current flow pattern only effective for 1:2 or 2:1 flow rate ratio of hydrogen and oxygen gases. Apart from that, the research article of Mahesh Kumar Yadav et al. [2] have also searched that as flow rate increases then generation of power also increases. Moreover, A Syampurwadi et al. [3] have also discovered that performance of PEM fuel cell stack can be affected by number of cell and gas flow rate. However, if flow ratio equal for counter current pattern then it shows high fluctuation in current density and power generation. While, cross flow pattern is highly effective for 1:1 flow rate ratio of gases. In addition, this flow pattern and flow rate ratio gives high power generation compared to former 2 parameters.

Here, the graphical representation is shown for clarification and comparison of 3 conditions.

Graphs of Power

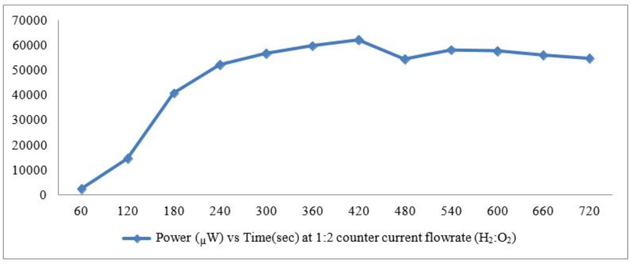

Figure 3: Graph of 1:2 flow rate (Counter Current).

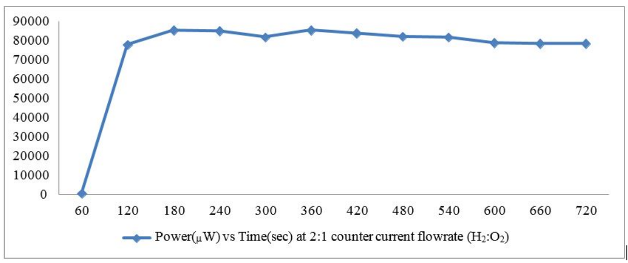

Figure 4: Graph of 2:1 flow rate (Counter Current).

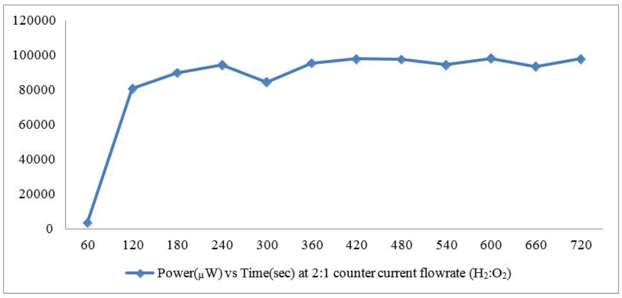

Figure 5: Graph of 1:1 flow rate (Counter Current).

Furthermore, some researchers are focusing on to modify Nafion membrane to improve efficiency of PEMFC. Farqad Saeed et al. [4] have used SiO_2 in Nafion dispersion using solgel method. Therefore, this modification has high efficiency compared to former Nafion membrane. Adding to this, temperature and pressure change can also affect the current density of PEM fuel cell and it is higher as temperature and pressure increase as per research of Mehdi Amirinejad et al. [5].

Conclusion

From this experiment, first conclusion that can be derived is hydrogen flow rate needs to be more compared to oxygen flow rate because hydrogen is the limiting reactant in this process. Due to above mentioned reason keeping hydrogen flow rate more in comparison to oxygen would yield better result i.e. better current density. Therefore, 2:1 (H_2:O_2) flow rate of gases is optimum for counter current flow pattern. For same flow rates of hydrogen and oxygen (1:1), cross current flow is more preferable than counter current flow because in this situation counter current flow gives more fluctuation and less current density. Apart from this, as pressure, temperature and number of fuel cell stack increase then current density and power generation also increase as per researches. Therefore, combination of these 2 researches can be more beneficial at economical level.

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