THE FUEL CELL, AN ECOLOGICAL AND EFFICIENT SOLUTION TO PRODUCE ELECTRICITY

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Abstract

Using the hydrogen fuel cell and the methanol fuel cell to produce electricity, represent a high efficient solution and an ecological friendly method. The combustion is based on hydrogen and methanol that can be obtained properly and during the functioning of the fuel cell the pollution is very low.

Key words: fuel cell, hydrogen, energy, pollution, environmental protection

INTRODUCTION

The hydrogen fuel cell is using hydrogen and oxygen to produce energy and water. In the same time the hydrogen used in the fuel cell can be obtained in the electrolysis process using water and energy.

There are no air pollution, no waste, but we can have a good efficiency of the process.

MATERIAL AND METHOD

The hydrogen fuel cell used for experiments was fabricated by Heliocentris Energiesysteme GmbH, like Fig. 1.

The same device can be used to produce energy and also to produce hydrogen.

The goal is to present the achievements in terms of efficiency and environmental protection of the fuel cells and also to fallow the research work in this domain in University of Oradea.

Producing the hydrogen

To produce hydrogen by electrolysis, using the reversible fuel cell, is different comparing to the simple electrolysis using a mixture water and salt.

The fuel cell is using distillated water, without any chemicals, which can damage the membrane of the cell. The chemical reaction is:

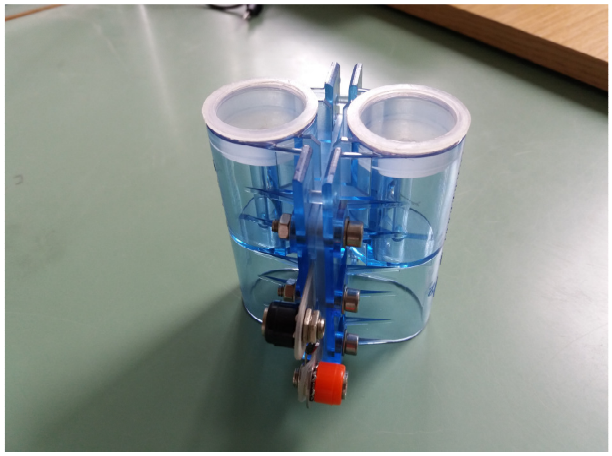

Fig. 1. Hydrogen fuel cell- reversible device, Heliocentris

Reduction	Anode:	$4\,H^+ + 4\,e^- \rightarrow 2\,H_2$	(1)
Oxidation	Cathode:	$2\,H_20 \rightarrow O_2 + 4\,H^+ + 4\,e^-$	(2)
	Overall:	$2\,H_20 \rightarrow 2\,H_2 + O_2$	(3)

$\Delta\,H = +\,285.8$ kJ/mole (4)

Water breaks down, using the device, in two parts hydrogen and one part oxygen.

The electrolysis device is using a membrane, present in the MEA (Membrane/Electrode Assembly), that allows to flow the hydrogen ions only in one direction (LANL, 2016). In conclusion:

Electricity + water = hydrogen+ oxygen

The device is connected to a source of electricity, voltage max. 2 V and current max. 160 mA, and filled with distilled water.

The oxygen and hydrogen is collecting in the top of the cylinders, the volumes are shown in Fig. 2. The water is pushed into the reservoir.

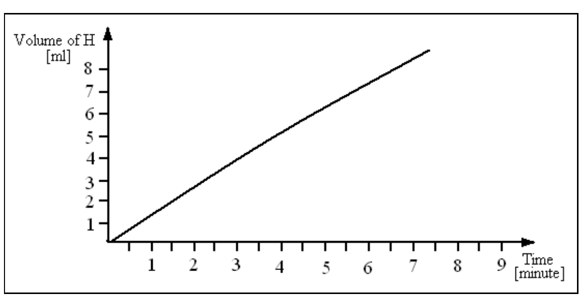

Fig. 2. Hydrogen collected

The fuel cell producing electricity

The principle for a hydrogen fuel cell is:

Hydrogen + oxygen = water + electricity

Like shown in Fig. 3, if we supply hydrogen on the anode and oxygen on the cathode, on the external circuit we obtain electricity.

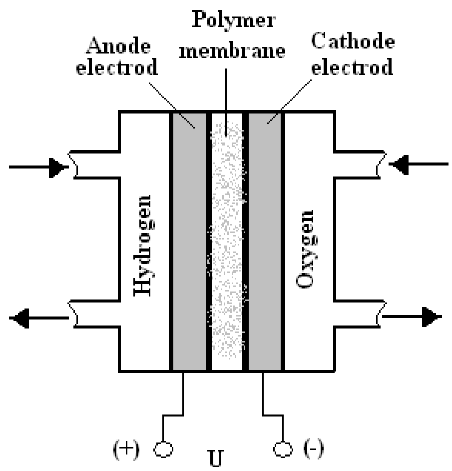

Fig. 3. Hydrogen Fuel Cell -principle

The reaction inside the cell is:

Oxidation Anode: $2H_2 \rightarrow 4H^+ + 4e^-$ (5)

Reduction Cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_20$ (6)

Overall: $2\,H_2 + O_2 \rightarrow 2\,H_20$ (7)

$\Delta H = -\,285.8$ kJ/mole (8)

A simple fuel cell is composed by a MEA (Membrane/Electrode Assembly), and two separated gas field flow plates, for oxygen and for hydrogen (Larmanie, Dicks, 2000).

The membrane called PEM (Proton Exchange Membrane or Polymer Electrolyte Membrane) is based on a polymer called nafion. The membrane shown in Fig. 4, has applied on the both sides a carbon layer , the support for the catalyst, usually platinum, very thin 3--5 nm (Heliocentris, Power solutions; Heliocentris, Academia).

Fig. 4. The fuel cell and the PEM - membrane, Heliocentris

Hydrogen molecules enter on the anode side of the cell and oxygen enters on the cathode side. The hydrogen protons flows through the PEM membrane to the cathode, there they combine with the oxygen molecules and the free electrons to form water. The hydrogen molecule releases its electrons, which flows from the anode electrode, through the external electric circuit to the cathode electrode, to obtain electricity (FuelCells.org; Hoffmann, 2012).

The hydrogen fuel cell is electrochemically converting hydrogen and oxygen gases, into electricity and water.

RESULTS AND DISCUSSION

The efficiency of the hydrogen fuel cell system

In order to determine the efficiency of the producing energy process using the hydrogen fuel cell, we need to find out the efficiency of the electrolysis and also the efficiency of the fuel cell (Smittinger, Vahidi, 2008).

For the electrolysis the efficiency is:

$$\eta_{El} = \frac{\textit{Energy of the hydrogen obtained by electrolysis}}{\textit{Electrical energy used to produce the hydrogen}}$$

For the fuel cell, the efficiency is:

$$\eta_{FC} = \frac{\textit{Energy produced by the fuel cell consuming the hydrogen obtained by electrolysis}}{\textit{Energy of the hydrogen used}}$$

During the experiments, in the Laboratories of the University of Oradea, we obtained an average for the efficiency:

$\eta_{El} = 80{,}6\%$ and $\eta_{FC} = 39{,}8\%$

The global efficiency of the system "electrolysis - fuel cell" is :

$\eta_{global} = \eta_{El} \ x\ \eta_{FC} = 80{,}6 \ x\ 39{,}8 = 32{,}07\ \%$

The efficiency of the fuel cell is around 40%, the difference represents power loses by heating, which is relatively high, 60%. Due to the technologies, a part of the loss can be recovered, around 60%-70%. That means the energy recovered by heating can be 60% x (60-70)% = (36-42)%.

The conclusion is, if we are recovering the energy loses by heating the global efficiency can be:

$\eta_{global\ recov} = 32{,}07\ \% + (36\text{-}42)\% = (68\text{-}74)\%$

which is economically interesting.

In the University of Oradea, the Electrical Engineering Department, after 2010, have been made researches regarding the behavior of the hydrogen and methanol fuel cells, in certain conditions of temperature and external mechanical vibrations, in order to increase the efficiency of the fuel cell.

The ecological impact of the fuel cells

For a very long time in the history, the water was considered an element. The scientists R. Boyle, H. Cavendish and A. Lavoisier, have proved that the water is formed by two gases and Lavoisier gave the name to hydrogen.

There are many ways to produce hydrogen. The electrolysis is one of them, in production of sodium hydroxide. It can be obtained also by reacting sodium or calcium with water. There are some biological possibilities to produce hydrogen by micro-organisms or algae in special conditions (Dincer, Acar, 2015).

Using a chemical reaction hydrocarbons-water, the hydrogen can be obtained from methanol, biogas and natural gas.

If we are producing hydrogen using a PEM - Proton Exchange Membrane, and if the electrical energy comes from the sun using a photovoltaic element, the process is 100% environmental clean (AHA).

In Table 1, we are comparing the sources of energy, fossils and renewable, from the point of view of production, environment and coast (Lenzen, 2009; Bazmi, Zahedi, 2011; Dincer, Acar, 2015).

Table 1

States of electricity generation from primary energy sources

Source of energy	Annual generation (TWh/y)	Capacity factor (%)	Mitigation potential (GtCO2)	Energy requirements (kW hth/kW hel)	CO2 emissions (g/kW h)	Production cost (US¢/kW h)
Coal	7755	70–90	N/A	2.6–3.5	900–1200	3–6
Oil	1096	60–90	N/A	2.6–3.5	700–1200	3–6
Gas	3807	55–65	N/A	2–3	450–900 65–	4–6
Nuclear fusion	2793	86	>180	0.12	200	3–7
Biomass	240	60	100	2.3–4.2	35–85	3–9
Geothermal	60	70–90	25–500	N/A	20–140	6–8
Hydro (large scale)	3121	41	200–300	0.1	45–200	4–10
Hydro (small scale)	250	50	150	N/A	45	4–20
Ocean	5	20–30	300	0.2	150	15–25
Solar (PV)	12	15	25–200	0.4–1	40–200	10–20
Solar (CSP)	1	20–40	25–200	0.3	50–90	15–25
Wind	260	24.5	450–500	0.05	65–80	3–7

The hydrogen can be stored and can supply fuel cell generators of electricity till 250kW, forming a decentralized sustainable energy system. The generators using hydrogen fuel cells have mobile and stationary applications.

The stationary applications are power for homes, between 6 to 250 kW and also suppliers for mobile devices like phones, heaving a long period between recharges, till 100 hours (Parson, 2000).

The mobile applications, the fuel cells for transport, are a very interesting application, if we are estimating that more than 55% of the pollution in the urban zones is caused by classical vehicles.

The vehicles based on Carnot cycle, are not very efficient, the figures are starting from 15% till 25% theoretically, but the efficiency of a fuel cell car is around 40%.

The hydrogen fuel cell car is a zero emission vehicle, with some technical advantages like: high power density, rapid acceleration (no more than 55kW needed for a medium car), quick refueling, costs very close to the classical motors (Frenette, Forthoffer, 2009).

The space occupied by a fuel cell engine is comparable with the space for a classical engine. Of course together the fuel cell stacks, we need a lot of other components, like: a compressor to supply oxygen, a humidifier for the PEM, a system to recover the heat, an electrical control system (Louis, 2001; Hockaday, Navas, 1999).

CONCLUSIONS

Hundreds of years, the economy was based on the energy obtained from the fuels coming from carbon. The need of energy is increasing every year by 2%, that means we should think to a sustainable and decentralized system. The data from the International Energy Agency for 2012 are states that the total electricity production was 22,6 TWh, that came 67,9% from fossil fuels primary energy, causing the 99,5% of the greenhouse gasses emissions.

There is only one solution: clean energy, in order to obtain sustainability, by better use of resources, environment, efficiency, coasts and security. The fuel cells can be a solution for the energy in industry, in transport and in household.

But there are still many issues remains to overcome, first of all regarding the costs and lives of fuel cells (Sorensen, 2012). Secondly, the storage raises complex issues (Becherif et al., 2015), and, in the meantime, the various risks assessments, like the liquid hydrogen use risk assessment and establishment of safety measures (Kikukawa et al., 2009), is still insufficient.

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