The Analysis of the Energetic Regime for an Experimental Kit Supplied by a Fuel Cell

eng. Dan Milici[1], eng. Mariana Milici[1]

[1] *University of Suceava, ROMANIA, Universitatii Street, 1, Suceava – 720225, RO, phone: +40.230.216147, dam@eed.usv.ro*

Abstract- This paper presets a study of a fuel cell placed on an experimental car kit and an analysis of the energetic regime for this kit, supplied by the fuel cell and by a solar panel. It was estimated the efficiency of the supply elements. The energetic regime at the level of supply of kit motor depends by the illumination degree of solar panel and by the driving torque that the motor must to develop it for motion. These factors will influence also the conversion processes at fuel cell level.

I. Introduction

The THAMES & KOSMOS FUEL CELL CAR & EXPERIMENT KIT gives a student the opportunity to develop a thorough, working knowledge of a unique energy source which holds much promise for the 21st century. In addition to a state-of-the-art fuel cell care model, this kit contains 30 experiments and demonstrations which are supported by detailed explanations.

We have all heard about global warming, the greenhouse effect, environmental pollution, and smog. We are all concerned about toxic emissions into the air we breathe. We know that these changes to our environment are, in varying degrees, the results of our own human activities. And although there is debate about the exact causes and relations, in the end no one source alone will turn out to be the culprit. It is, however, established that industry, traffic, power stations, and also every household introduce great quantities of contaminations to our air and environment. Many of us are engaged in increasing discussion about how we can mitigate these negative impacts in the future. Several ideas for more environmentally friendly vehicular traffic and energy production have been proposed and today many scientists and engineers are seeking to turn these ideas into reality.

One of these ideas is the step-wise transition of energy production to renewable sources of energy. The word “renewable” means nothing other than “self-producing” or “self-replacing”, which means that nothing is really consumed. For example, a great plant grows by absorbing carbon (carbon dioxide) from air. When the plant decays, exactly as much carbon dioxide is released as the plant absorbed from the air during its lifetime cycle. This is in contrast to, for example, lignite, coal, mineral oil and natural gas. These fossil fuels are the remains of plants that grew millions of years ago. At that time there was plenty of carbon dioxide in the air, and the climate was totally different than today. The plants were since covered by soil and captured underground. As s result the carbon dioxide they had absorbed was essentially withdrawn from the cycle. If this stored carbon dioxide is brought back into the air by burning the fossil fuels, then the composition of the air will slowly, but surely, return to the same as it was several million years ago. At that time there were, however, no humans, and they could not even have lived in this air.

Additionally, the scarcity and rising cost of fossil fules are causing increasingly serious impacts on the global economy, thus making the case for the use of fuel cells and other non fossil fuels even more compelling.

The fossil fuels will be consumed ao some pint, even though the exact point in time is being debated. It is, however, unimportant whether this occurs in 20, 50 or 200 yers. It is certain that it will happen. Thus, the search for renewable energy sources and renewable raw materials is essential.

II. The Fuel Cell

Our fuel cell is a reversible PEM fuel cell. The abbreviation PEM refers to the membrane that separates the oxygen side from the hydrogen side of the cell. The letters PEM stand for Proton Exchange Membrane. A thin foil of the polymer Nafion serves as membrane in our fuel cell. There are also other ways to separate hydrogen and oxygen sides from each other. Reversible means that all processes can run in both directions; in other words, the cell can operate both as fuel cell and as electrolysis agent.

The electrical contact plates in our fuel cell (electrodes) have very different names since very different things happen on them: the electrode on the hydrogen side is called the anode; the electrode on the oxygen side is called the cathode. On the anode, electrically neutral hydrogen molecules which are stored in the hydrogen tank are oxidized via electron donation into hydrogen ions. These positively charged hydrogen ions migrate ("diffuse") through the polymer membrane towards the negatively charged cathode. The membrane has such properties that hydrogen ions, also known as protons, fit through its pores but the larger oxygen ions do not (hence the name proton exchange membrane).
On the cathode, the hydrogen ions react with the oxygen present there and the electrons that are provided by the electrical conductor leading to the cathode. The net result is the formation of water. In some sense, hydrogen and oxygen ions are being reassembled into water molecules. While it was necessary to put energy into the dissociation of water molecules during electrolysis, now upon recombination of the ions energy is released. In this way, an electrical voltage is produced across the fuel cell. If we connect an electrical load to anode and cathode, e.g. an electric motor, electrons flow from anode to cathode, in other words an electric current flow and the motor runs.
Since the conversion of hydrogen and oxygen takes place catalytically, the electrodes themselves do not change in these chemical reactions. The combustion is said to be "cold" as no flames are involved. Nevertheless, heat is released in the process. Maybe we can fell a warming of the fuel cell.
Chemically, the following reactions occur at the electrodes of the fuel cell:

anode:	$2\,H_2 \rightarrow 4\,H^+ + 4\,e^-$	electron Donation (oxidation)	
cathode	$O_2 + 4\,H^+ + 4\,e^- \rightarrow 2\,H_2O$	electron uptake (reduction)	(1)
net reaction	$2\,H_2 + O_2 \rightarrow 2\,H_2$		

The water production at the cathode (oxygen side) can be easily observed. Pay attention to it when the fuel cell generates current. The larger the current flow, the faster water is regenerated from the hydrogen and oxygen gases.
An overview of the different fuel cell types is presented in the table below:

Name	Electrolyte	Anode Gas	Cathode Gas	Temperature	State
AFC Alkaline Fuel Cell	Potash	Hydrogen	Oxygen	below 80 °C	Commercial
PEMFC Proton Exchange Membrane Fuel Cell	Polymer Membrane	Hydrogen (direct or from reformation of methane or methanol)	Oxygen or Atmospheric Oxygen	to 120 °C	Being Developed
DMFC Direct Methanol Fuel Cell	Polymer Membrane	Methanol	Atmospheric Oxygen	90 ÷ 120 °C	Being Developed
PAFC Phosphoric Acid Fuel Cell	Phosphorus	Hydrogen (direct or from reformation of methane or methanol)	Atmospheric Oxygen	200 °C	Commercial
MCFC Molten Carbonate Fuel Cell	Alkali-Carbonates	Hydrogen Methane	Atmospheric Oxygen	650 °C	Being Developed
SOFC Solid Oxide Fuel Cell	Ceramic-Oxide	Hydrogen Methane	Atmospheric Oxygen	900 ÷ 1000 °C	Being Developed

We can observe that the cell has warmed up. Not only current was generated by the conversion of the gases, but also heat. When the fuel cell is connected to the motor and the gas tanks are filled with hydrogen and oxygen then

- the motor being to turn
- the gas volumes being to decrease.

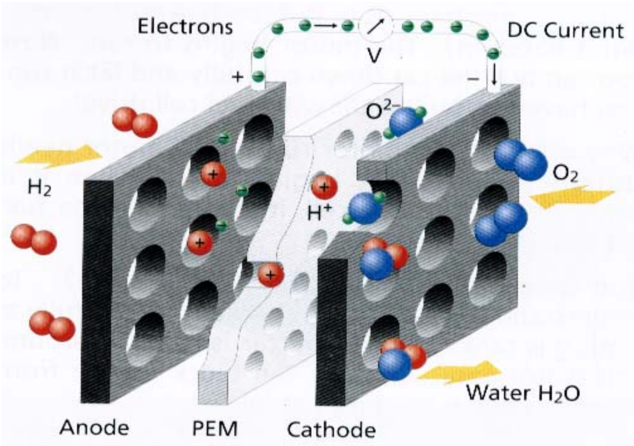

Figure 1. Schematic picture of combine the hydrogen and oxygen molecules into water [1]

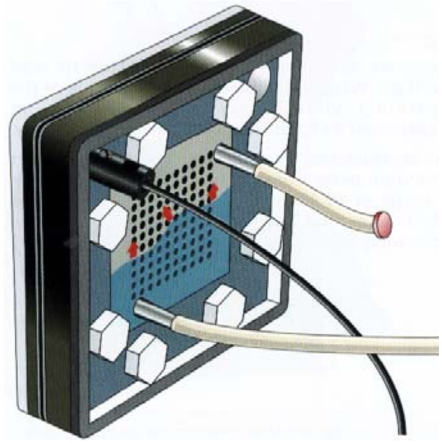

Figure 2. The Power cell [1]

III. Experimental data

The experimental kit has a hybrid supply which permits the electrical energy generation by solar energy for motion and for the water conversion in hydrogen and oxygen (when exists light radiation incident to the solar panel) and electrical energy generation at the level of fuel cell via recombination of the hydrogen with oxygen (when the panel is disconnected or not exists solar radiation incident to this).

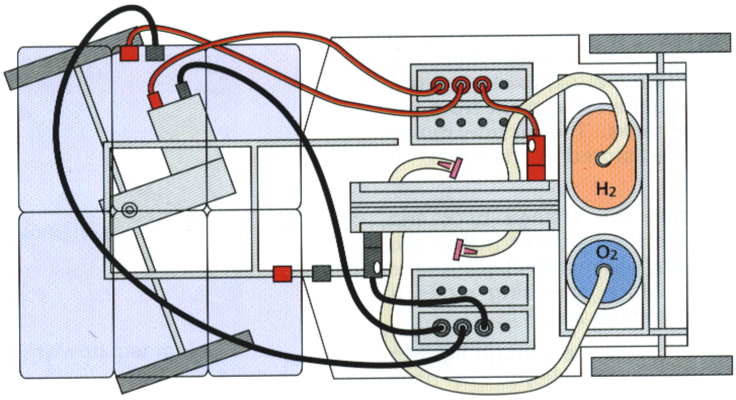

Figure 3. Image of the robot

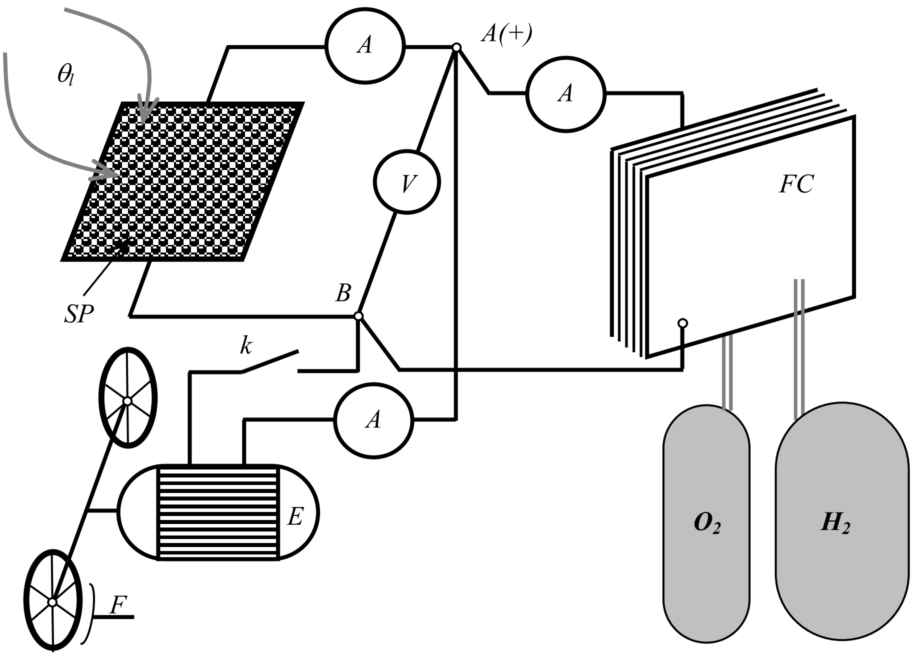

Figure 4. Electrical main application
SP – solar panel, *FC* – fuel cell, *E* – electrical engine, *F* – breaks, θ_l –

The experimental board permits to overview the current and voltage in all electrical branch of circuit (figure 5) on hole regime, on load regime and on other some intermediary situations.
In the following figure is presented the power's variation on the circuit's branches at the variation of incident illumination intensity and transferred power between the solar panel and fuel cell, at water dissociation in hydrogen and oxygen, when the motor is not connected. The measuring error is 3 % due to the low value of estimated power.

IV. Conclusions

The energetic regime at the level of supply of kit motor depends by the illumination degree of solar panel and by the driving torque that the motor must to develop it for motion. These factors will influence also the conversion processes at fuel cell level.
The hydride kit efficiency will be depending on the conversion efficiency of solar cells and of the fuel cell. The optimal operation of fuel cell is obtained in case of distillated water using and of a high voltage between the terminals. At the same time, this efficiency changes its values between (0,49÷0,52)%, during of several consecutive conversions and during of a complete conversion.

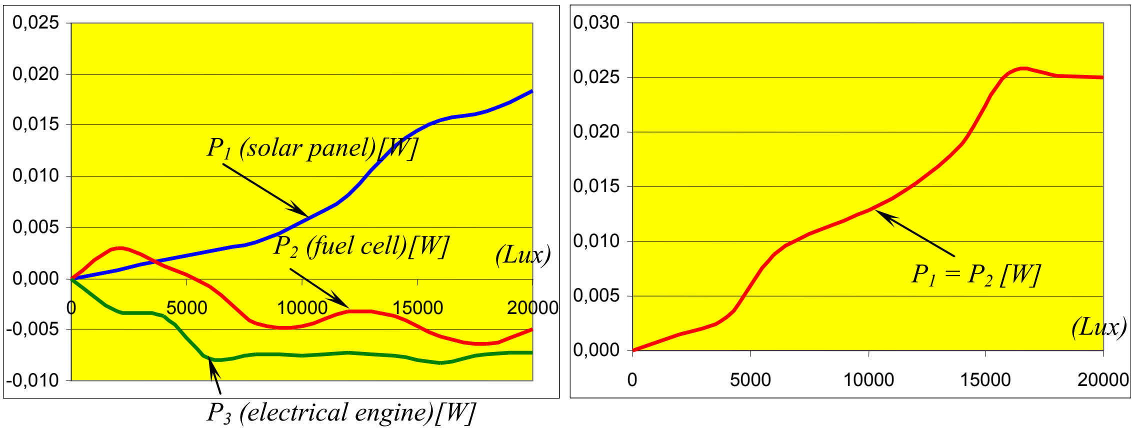

Figure 4. Experimental data

References

[1] D. Bahnemann, F. Pujiula, C. Berge, *Fuel Cell Car & Experimental Kit*, Thames & Kosmos, LLC, Newport, RI USA, 2000.
[2] G. Asch, *Les capteurs en instrumentation industrialle*, Dunod, Paris, 1991.