

FUEL CELL TECHNOLOGY

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Abstract. The fuel cells (FCs) are electrochemical devices that can transform directly the chemical energy of a fuel in electric energy. By this way, they generate less entropy, consequently are most efficient and produce less pollution than conventional electricity generation systems. At the beginning, when they were discovered, in the XIX century, by Sir William Grove, the FCs didn't have commercial use because of some problems, mainly because of problems with materials used on their construction. This scenario however had some changes after 60's decade, when the North American space program begins to use them in his missions. Today, the FCs are recognized like one of the most promising technologies for electric generation that can solve a lot of problems confronted by the world energetic sector. On this article, will be discussed the functioning of the FCs, and too, will be described some hybrid systems used to obtain a higher efficiency.

Keywords: fuel cell, efficiency, energy, pollution, hybrid systems,

INTRODUCTION

The FCs have been known since the nineteenth century when they were discovered by Sir William Grove, but they were for a long time without real applications, until the 60s, when the American space project began to use these devices in their missions, these cells were very expensive and required extremely pure oxygen and fuel, preventing its commercial use.

Since then, much research has been done, causing the FCs no longer require extremely pure fuels, and neither of rare metals for its construction. Thus, although timidly, they are already gaining market in the power generation.

PRINCIPLE OF OPERATION

Fuel cells (FC) are electrochemical devices that transform chemical energy in the fuel into electricity without the restriction thermodynamic conversion of heat into work. Them converting fuel into electricity takes place directly, through its oxidation at the anode (negative pole), while oxygen is reduced at the cathode (positive pole).

As the generation of electricity passes through fewer phases, it is expected that there is less loss than conventional devices that require more stages, as diesel engines and gas turbines.

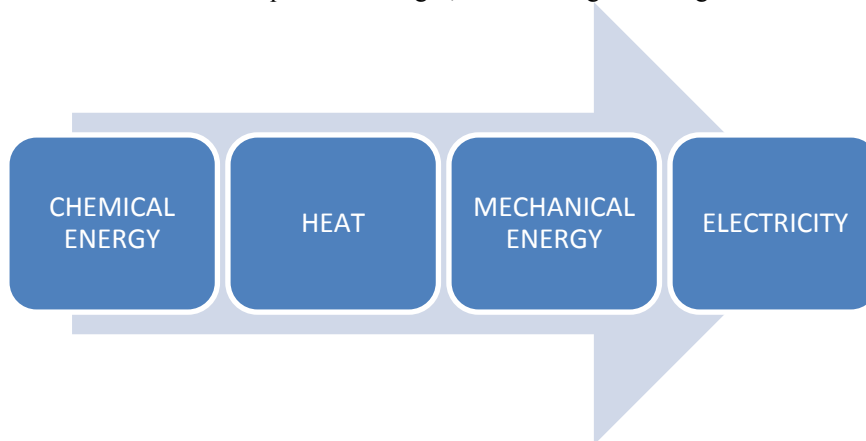


Figure 1: thermodynamic conversion of energy.

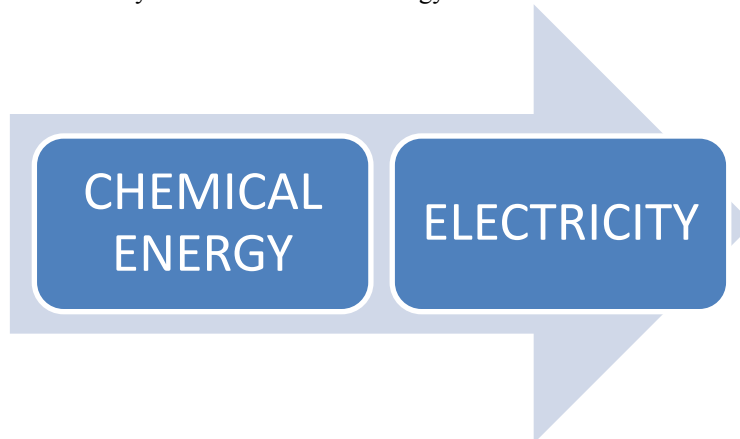


Figure 2: Electrochemical Energy Conversion.

Fuel cells can be classified in various ways, but the most usual is classifies them according to the electrolyte used and consequently the operating temperature, as can be seen below:

CELLS OF LOW TEMPERATURE OPERATION

Alkaline cells	AFC	KOH	80 ° C
Cells with proton exchange membrane	PEMFC	currently Nafion [®] membrane	80 ° C
phosphoric acid fuel cell	PAFC	H ₃ PO ₄	200 ° C

CELLS HIGH TEMPERATURE OPERATION

Molten carbonate fuel cell	MCFC	$\text{Li}_2\text{CO}_3 / \text{K}_2\text{CO}_3$ - Eutectic.	700 ° C
Solid oxide fuel cell	SOFC	ZrO_2 stabilized with Y_2O_3	900 ° C

FUEL

Hydrogen is the most abundant chemical element in the universe, but owing to its high reactivity cannot be found freely on the earth, always being in some compost. So unlike fossil fuels, which can be extracted or mined, the hydrogen must be produced.

To produce hydrogen, may be used various materials like oil, natural gas, coal or water.

Currently hydrogen comes mainly from reform (heterogeneous catalytic transformation) of natural gas with water vapor. Natural gas was chosen because of the high process efficiency and relatively low cost (Kushnir, 2002). However, this process does not lessen the dependence on fossil fuels.

Hydrogen production from biomass is promising, but this research is still new, and is in development phase. When we say biomass, basically we are including all kinds of organic matter such as plants, driftwood, garbage, etc.. There is currently no method for reforming of biomass that can be applied commercially, but the method is in a high temperature process which converts the biomass into hydrogen and carbon dioxide.

The reform process is a process that requires a huge amount of thermal energy, and obeys the following reactions which can be seen below:

Reforming of natural gas (methane):



Reforming of hydrocarbons:



Reform of methanol:



Finally, hydrogen can also be produced by electrolysis of water. In this process an electric current through the water separating into its basic constituents: hydrogen and oxygen.

Electrolysis of water:



This process is particularly interesting, because it opens the possibility of using renewable sources such as wind, tidal, hydropower, etc. for the production of hydrogen. One of the uses of this case would produce hydrogen when the system was energy to spare, so the hydrogen would be a form of energy storage, so it can be used later.

In cells that work at high temperatures, the reform can occur in the body of the cell (SOFC and MCFC mainly) where harnesses the heat produced by them for chemical reactions.

STORAGE OF HYDROGEN

Hydrogen is a gas at room temperature, so one of the greatest challenges for the deployment of fuel cells, is to find a viable way to store hydrogen without that occupy much space, or lose much of their ability energy.

Currently there are several ways of hydrogen storage, if it is desired to store it at room temperature, can be done at high pressure, in the same way that you do with vehicles that use natural gas. However, gaseous fuels have a low energy per unit volume, compared to liquid fuels, so an alternative

would be to cool the hydrogen at low temperatures, making the liquid. But that would bring other problems, how to get tanks that withstand these temperatures without losing its strength, and to keep the temperature inside.

Cylinders made of stainless steel as are used in vehicles using natural gas as fuel, the cylinders withstand pressures of the order of 20 MPa, are also being developed cylinder made of composite bore for liquid hydrogen.

CLASSIFICATION OF A FUEL CELL

Currently on the market there are several types of fuel cells with several different features. The most common way is to classify them according to the electrolyte they use. In the table below can be seen the cell types with their electrolytes, as well as some of their characteristics.

Type	Electrolyte	Species transported	Advantages	Disadvantages	Temperature Range ° C	Applications
Alkaline (AFC)	KOH	OH^-	High efficiency	Sensitive to CO_2 Ultra-pure gases, without reform of fuel	60-90	Spacecraft Military applications
Membrane (CFMP)	Polymer Nafion®	H_3O^+	Flexible Operation High power density and efficiency	Cost of the membrane and catalyst Contamination of the catalyst with CO	80-90	Vehicles Spacecraft Mobility
Phosphoric acid (PAFC)	H_3PO_3	H_3O^+	Further technological development	Control of the electrode porosity Sensitivity to CO Limited efficiency due to corrosion	160-200	Stationary units
Molten carbonate (MCFC)	Molten carbonate	CO_3^{2-}	Tolerance to CO / CO_2 Ni-based electrodes	Problems materials Need to recycle CO_2 Interface phase unwieldy	650-700	Units estaconarias
Ceramics (SOFC)	ZrO_2	O^{2-}	High efficiency (Kinetic favorable) Reforming the fuel cell can be made in	Problems materials Thermal expansion Need to pre-retirement	800-900	Stationary units

FUEL CELLS OF SOLID OXIDE (SOFC)

The SOFCs are one of the most promising technologies to market for stationary electricity generation, because they present a good efficiency, and virtually non-polluting (Amaral, Matos, Boa Ventura Benedicto, Alencar, 2005). These cells operate at high temperatures (800°C - 900°C) therefore do not need to use as noble metal catalysts, such as high temperature promotes the reaction kinetics, making it possible to perform even if the reform fuel cell in the body, (Cobas, 2006). But this high temperature also makes special materials are required, temperature resistant, leaving FC with a high price.

A SOFC has three main parts, which are: the fuel electrode (anode), the air electrode (cathode) and the electrolyte. In the figure below it can be seen that setting.

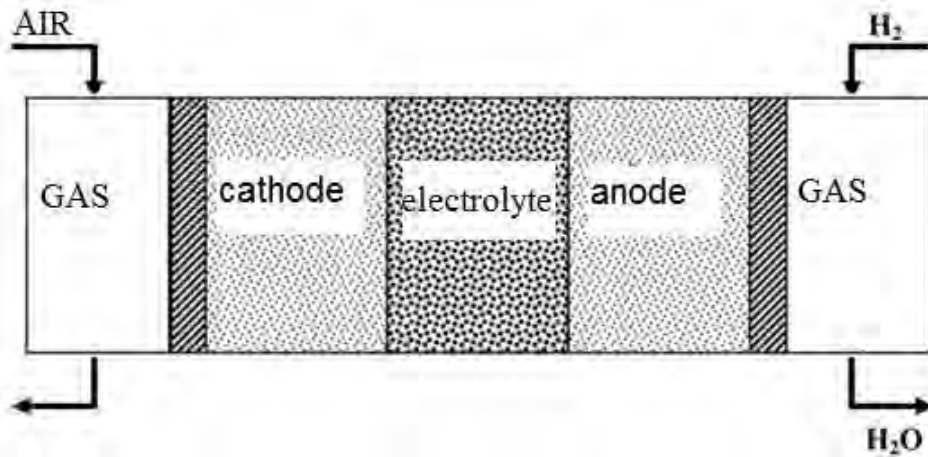


Figure 3: Schematic of a SOFC (Amaral, Matos, Boa Ventura Benedicto, Alencar, 2005).

The SOFCs are designed with two main geometries: tubular and flat. The tubes are already produced for some time, since the flat is a recently technology, it still needs much development.

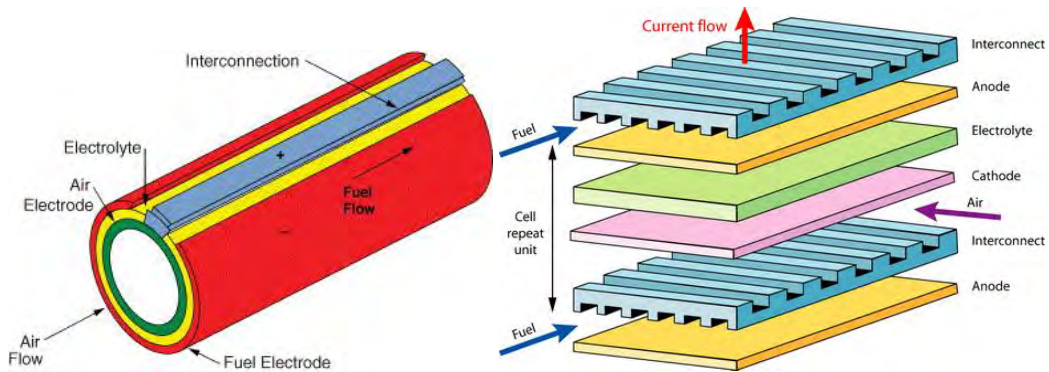


Figure 4: tubular configuration.

Figure 5: planar configuration.

ELECTROLYTES

The electrolyte is the component of the SOFC take charge of oxygen ions from the cathode to the anode, and also forms part of the triple-phase electrode-electrolyte gas ensures that the breaking of the H₂ molecule creating a flow of electrons through the external circuit (Gonzales, 2007).

The electrolyte must appear stable in reducing environment (the cathode), and in an oxidizing environment (anode). The electrode should be free of porosity, as it should not allow the passage of the reactants, but he should be able to allow the passage of oxygen ions from the cathode to the anode.

HYBRID SYSTEMS

Called hybrid systems, any systems who use more than one type of technology. In this paper, the hybrid system is discussed which uses fuel cells and gas turbines. This type of hybrid system has been the subject of considerable research by presenting high efficiency rates.

With gas turbines, it is possible to produce energy at low cost, and low emissions, but these turbines have limited its effectiveness by the combustion process. As for the fuel cells have high efficiency and low emissions, but they are still too costly for most applications.

The fuel cell used in the hybrid system is a SOFC, because that rejects heat at high temperature, allowing the co-generation (co-production of electricity and heat) and can operate in conjunction with gas turbines (Brayton cycle) or turbines steam (Rankine cycle) (Sordi, Silva, Lopes, Souza; 2007).

Through a hybrid system that employs a fuel cell and a gas turbine, it is possible to achieve efficiencies higher than would be obtained in the two technologies alone. At a cost that can be intermediate.

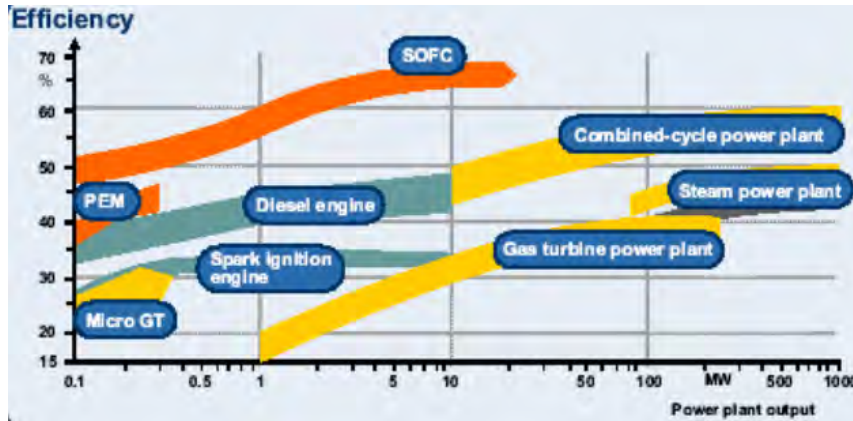


Figure 6: Efficiency of different electricity generation technologies and power ranges of application (Hassmann apud Cobas, 2006).

Typically, a SOFC works with temperatures ranging from 950 °C, with this temperature level of the heat released in the exhaust is big enough to be used in the operation of a microturbine. At the same time, the heat produced by the turbine can be used for preheating the gases used in CF. Therefore, it is possible to increase system efficiency through an additional combustion exhaust gas coming out of FC in the combustion chamber of the turbine (Bohn, 2005). This means that these hybrid systems can be a promising technology for the energy supply in the future. More research is needed to make you turn down the volume of CFs and that increases its specific power.

CONFIGURATIONS

FC-TURBINE INTEGRATION THROUGH HEAT EXCHANGER

The simplest way to build a hybrid FC / gas turbine is connecting the two components through a heat exchanger. In this case, the FC ejects hot compressed air in the hearth of the turbine. Meanwhile, the gases that go into the anode and cathode of the FC are heated by the exhaust gas turbine, these gases that are a result of combustion of residual fuel contained in the exhaust of the FC. (Bohn, 2005). As the exhaust gases are already CF temperature close to the operating temperature of the turbine, it is not necessary that too much fuel is consumed to warm the gases going to the turbine. As the exhaust temperature is too high, it is necessary to use materials that withstand heat, both in the hearth, as the connection that connects the FC to heat exchanger.

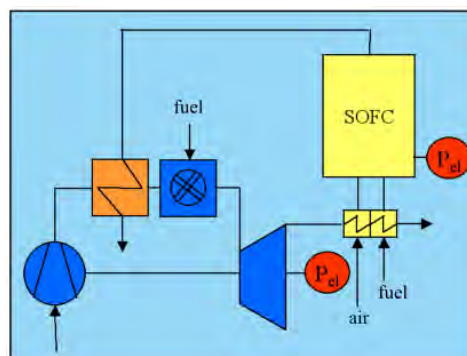


Figure 7: Integration of a Micro Turbine and a SOFC by a Heat Exchanger (Bohn, 2005).

At a temperature of 950 ° C in the SOFC of 920 ° C at the turbine inlet and a pressure ratio of 6.5 is obtained with this system regenerative efficiency of 53%.

DIRECT INTEGRATION FC GAS TURBINE

Another way of combining FC with the gas turbine is through a direct integration of the two components. Thus, the SOFC can handle higher pressures, which is beneficial for there to be an increase in efficiency. With this configuration it is possible to obtain an efficiency of 56.6%, considering a normal intake of the turbine, and a working temperature of the SOFC 950 ° C. The exhaust gas of CF has about 15 to 20% of unburned fuel, this fuel can be used later in the turbine to increase the temperature. In the image below, can be seen the outline of a plan for direct integration FC gas turbine.

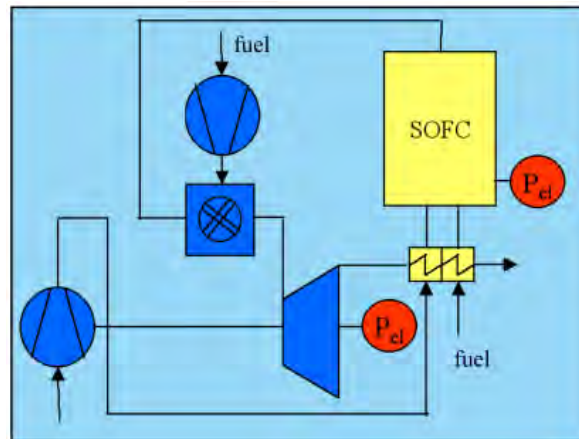


Figure 8: Direct Integration of a Micro Turbine and a SOFC (Bohn, 2005).

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