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A REVIEW OF FUEL CELL AND THEIR TYPES

Shailendra Kumar Bohidar[1], Prakash Kumar Sen[2], Arti Tirkey[3]
[1,2]Faculty, Mechanical Engg. Department, [3]Student of Mechanical Engineering
Kirodimal Institute of Technology, Raigarh, Chhattisgarh, India 496001

Abstract: This paper present the fuel cell used .Fuel cells have the potential to transform how we generate on-site electricity Fuel cell powered cars are probably one of the most dramatic new applications for them A fuel cell is like a battery in that it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical energy into electrical energy and also, as a by-product of this process, into heat. However, a battery holds a closed store of energy within it and once this is depleted the battery must be discarded, or recharged by using an external supply of electricity to drive the electrochemical reaction in the reverse direction.

I. INTRODUCTION

In the energy world, the less steps it takes to use or convert one energy form into another, the more elegant the system and Also the more efficient. Consider the process steps it takes to convert the energy in gasoline to motive power for a car:

• Convert chemical energy of gasoline to thermal energy (combustion)
• Convert thermal energy to mechanical power (push pistons)
• Convert mechanical energy to mechanical energy (rotational motion to rotational motion in crankshaft, transmission, and transaxle/differential.

This last step involves multiple transformations and trade-offs between torque and speed [i.e. gears]. It is even more complex for making electricity from coal, oil, or natural gas. All these conversion steps tend to rob the process of efficiency. A car is only about 18-22% efficient, that is 18-22% of the energy in the gasoline makes the wheels turn. All that heat radiating from a car is wasted gasoline energy, as is the sound of its operation (engine running, wheel sounds, exhaust noise etc.). What makes energy conversion processes like photovoltaic’s or solar cells so attractive is they are an example of direct energy conversion sunlight to electricity. This process makes no pollution, because energy is not wasted at conversion interfaces or process steps. Batteries are like this too, converting chemical energy directly to electricity; and so is the subject of this book fuel cells which also converts chemical energy directly to electricity. Fuel cells have the potential of being able to achieve energy conversion efficiencies in the range of 28-40%. Now that would be an interesting alternative to the internal combustion engines we now use in our cars. Fuel cells and batteries are direct energy conversion cousins. Thomas Edison had a visceral feel for this. He long ago, 100 years to be exact, championed the use of battery powered vehicles for most driving activities. The internal combustion engine to him was polluting, and bound to be limited by the future availability of gasoline fuel. There is even more potential benefit from fuel cells. The low temperature heat that is produced from large fuel cells can also be used to provide space heating to nearby structures. This is called cogeneration, the dual generation of energy for both electricity and heat. Under these conditions, fuel cell efficiencies can reach 80-90%; and remain clean for the environment. Versatile fuel cells offer a promising way to generate electricity and on a vastly decentralized basis. A fuel cell, on the other hand, uses an external supply of chemical energy and can run indefinitely, as long as it is supplied with a source of hydrogen and a source of oxygen (usually air). The source of hydrogen is generally referred to as the fuel and this gives the fuel cell its name, although there is no combustion involved. Oxidation of the hydrogen instead takes place electrochemically in a very efficient way. During oxidation, hydrogen atoms react with oxygen atoms to form water; in the process electrons are released and flow through an external circuit as an electric current. Fuel cells can vary from tiny devices producing only a few watts of electricity, right up to large power plants producing megawatts. All fuel cells are based around a central design using two electrodes separated by a solid or liquid electrolyte that carries electrically charged particles between them. A catalyst is often used to speed up the reactions at the electrodes. Fuel cell types are generally classified according to the nature of the electrolyte they use. Each type requires particular materials and fuels and is suitable for different applications. A fuel cell by definition is an electrical cell, which unlike storage cells can be continuously fed with a fuel so that the electrical power output is sustained indefinitely (Connivance, 1981). They convert hydrogen, or hydrogen-containing fuels, directly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water. The process is that of electrolysis in reverse. Because hydrogen and oxygen gases are electrochemically converted into water, fuel cells have many advantages over heat engines. These include: high efficiency, virtually silent operation and, if hydrogen is the fuel, there are no pollutant emissions. If the hydrogen is produced from renewable energy sources, then the electrical power produced can be truly sustainable. The two principle reactions in the burning of any hydrocarbon fuel are the formation of water and carbon dioxide. As the hydrogen content in a fuel increases, the formation of water becomes more significant, resulting in proportionally lower emissions of carbon. A fuel cell is an electrochemical device that combines hydrogen or other fuels and oxygen to produce electricity, with water and heat as its by-product. As long as fuel is supplied, the fuel cell will continue to generate power. Since the conversion of the fuel to energy takes place via an electrochemical process, not combustion, the process is clean, quiet and highly efficient – two to three times more efficient than fuel burning. • No other energy generation technology offers the combination of benefits that fuel cells do. In addition to low or zero emissions, benefits include high efficiency and reliability, multi-fuel capability, Operation flexibility, durability, and ease of maintenance. Fuel cells are also scalable and can be stacked until the desired power output is reached. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating for a home or office.

II. HISTORY OF FUEL CELL

The history of fuel cells begins with Sir William Groves, often referred to as the “Father of Fuel Cells”. This historical perspective is rapidly evolving, especially as world oil supplies are becoming tighter than ever. Many believe fuel cells to be the ideal long-term alternative to gasoline powered internal combustion engines, an automotive economy powered by clean and renewable hydrogen fuel. Starting in 1839, the dates shown in Exhibit A at the end of this booklet are considered to be approximate time periods for fuel cell development milestones. Sir William Grove (1811-96), a British lawyer and amateur scientist developed the first fuel cell in 1839. The principle was discovered by accident during an electrolysis experiment. When Sir William disconnected the battery from the electrolyze and connected the two electrodes together, he observed a current flowing in the opposite direction, consuming the gases of hydrogen and oxygen (Fig. 2). He called this device a ‘gas battery’. His gas battery consisted of platinum electrodes placed in test tubes of hydrogen and oxygen, immersed in a bath of dilute sulphuric acid. It generated voltages of about one volt. In 1842 Grove connected a number of gas batteries together in series to form a ‘gas chain’. He used the electricity produced from the gas chain to power an electrolyze, splitting water into hydrogen and oxygen (Fig. 3). However, due to problems of corrosion of the electrodes and instability of the materials, Grove’s fuel cell was not practical. As a result, there was little research and further development of fuel cells for many years to follow.

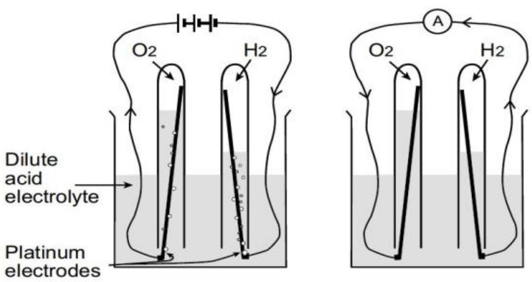

FIG1:- Fuel cell

III. BASIC OPERATION

Basically, a fuel cell is a device that converts directly the chemical energy stored in gaseous molecules of fuel and oxidant into electrical energy. When the fuel is hydrogen the only byproducts are pure water and heat. The overall process is the reverse of water electrolysis. In electrolysis, an electric current applied to water produces hydrogen and oxygen; by the process, hydrogen and oxygen are combined to produce electricity and water (and heat). A fuel cell can be seen with profit as a “chemical factory” that continuously transforms fuel energy into electricity as long as fuel is supplied. However, unlike internal combustion engines that can be regarded as factories as well, fuel cells rely on a chemical reaction involving the fuel, and not on its combustion. During combustion, molecular hydrogen and oxygen bonds are broken and electrons reconfigure into molecular water bonds at a picoseconds length scale. There is no possible way to “catch up” these free electrons and the net energy difference between molecular bonds in products vs. reactants can only be recovered in the most degraded form of energy, i.e. heat.

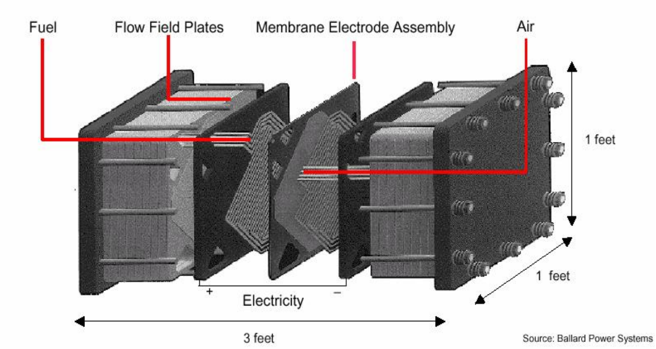

Fig.2- fuel cell power system

A Carnot cycle involving the transformation of heat into mechanical and electrical energy is then involved in conventional methods for generating electricity: these successive steps of transformation of energy severely limit the overall efficiency of the process (which is by definition the product of the efficiency of the different steps).In a fuel cell the direct conversion of the chemical energy of covalent bonds into electrical energy is made possible by the spatial separation of the hydrogen and oxygen reactants by the electrolyte. The electron transfer necessary to complete the bonding reconfiguration into water molecules occurs over a much longer length scale. This allows direct collection of electrons as a current in fuel cells and leads to fuel efficiencies two to three times higher than in internal combustion engines (depending on the fuel cell technology). Unlike batteries, there is no chemical transformation of any component of the fuel cell device during operation and it can generate power without recharging, as long as it is being fed with fuel. The unit fuel cell structure called the membrane electrode assembly (MEA) typically consists of an electrolyte in contact on its both sides with two electrodes, one negative electrode (anode) and one positive electrode (cathode). Fuel is continuously fed to the anode side and oxidant is continuously fed to the cathode side. Fuel cell reactants are classified as fuels and oxidants on the basis on their electron donor and electron acceptor properties. Oxidants mainly include pure oxygen and oxygen containing gases e.g. air, or halogens e.g. chlorine. Fuels include pure hydrogen and hydrogen-containing gases, e.g. methanol,

ethanol, natural gas, gasoline, biogas, diesel, etc.In the most straightforward case, i.e. the hydrogen fuel cell the combustion of hydrogen into water is split into two electrochemical reactions occurring at the anode and cathode, respectively, which are termed as the two half-cell reactions. There are a number of different fuel cell technologies that can be used for a variety of large and small applications. A popular technology today for potential application in homes, cars, and small commercial buildings, is the PEM, or Proton-Exchange-Membrane fuel cell. Its name describes what is going on inside the cell…an electrochemical reaction in which a hydrogen atom is split into proton and an electron. The proton travels directly across a membrane and combines with an oxygen atom to form water. Meanwhile, the free electron is routed through an external circuit as electricity.

IV. TYPES OF FUEL CELL

Technically, fuel cells are similar to batteries. Both are electrochemical energy conversion devices. A battery has its store of chemicals inside its own container. When the chemicals are exhausted, the battery is dead; and must be replaced or recharged. A fuel cell receives its chemical energy (hydrogen and oxygen) from the outside and can operate as long as those chemicals are supplied to it. It is a continuous battery. There are a variety of fuel cells available today, usually classified by the type of electrolyte used, but most make use of hydrogen and oxygen as the main chemicals. Beside the PEM fuel cell of interest to us here there are: Alkaline fuel cells (AFC)….one of the oldest designs, used in the U.S. space program. It is expensive and requires high purity hydrogen and oxygen. Phosphoric-acid fuel cell (PAFC)….can be used in small stationary power applications, and operates at higher temperatures than PEMs; and has a longer warm up time, making it unsuitable for automotive use

Fig.3:- Proton Exchange Membrane Fuel Cells

TABLE I : TYPES OF FUEL CELL

Fuel Cell Designation		Electrolyte	Temperature °C	Cell Efficiency (Load Partial Load)	Type of Application
Alkaline Fuel Cell	AFC	Aqueous KOH	60.. .90	50.. .60	Mobile, stationary
Polymer Electrolyte Fuel Cell	PEFC	Polymer electrolyte Membrane	50.. .80	50.. .60	Mobile, stationary
Direct Methanol Fuel Cell	DMFC		110.. .130	30.. .40	Mobile
Phosphoric Acid Fuel Cell	PAFC	H_3P0_4	160.. .220	55	Stationary
Molten Carbonate Fuel Cell	MCFC	Alkaline carbonates	620.. .660	60...65	Stationary
Solid Oxide Fuel Cell	SOFC	ZrO2	800.. .1000	55.. .65	Stationary

A. PEMFC – Proton Exchange Membrane Fuel Cells:

- Electrolyte: water-based, acidic polymer membrane
- Also called polymer electrolyte membrane fuel cells
- Use a platinum-based catalyst on both electrodes
- Generally hydrogen fuelled
- Operate at relatively low temperatures (below 100°C)
- High-temperature variants use a mineral acid-based electrolyte and can operate up to 200°C.
- Electrical output can be varied, ideal for vehicles

B. Alkaline Fuel Cells – AFC:

- Electrolyte: alkaline solution such as potassium hydroxide in water
- Commonly use a nickel catalyst
- Generally fuelled with pure hydrogen and oxygen as they are very sensitive to poisoning
- Typical operating temperatures are around 70oC
- Can offer high electrical efficiencies
- Tend to have relatively large footprints

C. SOFC – Solid Oxide Fuel Cells:

- Electrolyte: solid ceramic, such as stabilized zirconium oxide
- A precious metal catalyst is not necessary
- Can run on hydrocarbon fuels such as methane
- Operate at very high temperatures, around 800oC to 1,000oC
- Best run continuously due to the high operating temperature
- Popular in stationary power generation

D. Molten Carbonate Fuel Cells – MCFC:

- Electrolyte: a molten carbonate salt suspended in a porous ceramic matrix
- A precious metal catalyst is not necessary
- Can run on hydrocarbon fuels such as methane
- Operate at around 650oC
- Best run continuously due to the high operating temperature
- Most fuel cell power plants of megawatt capacity use MCFCs, as do large combined heat and power plants

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