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Recent Trends and Comparison in Fuel Cell Technology

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ABSTRACT

The fuel cells are an old technology. Problems have plagued their introduction. Present material science may make them a reality soon in specialized applications. The Solid Oxide Fuel Cell appears to be the most promising technology for small electric power plants over 1 kw. The Direct Alcohol Fuel Cell appears to be the most promising as a battery replacement for portable applications such cellular phones and laptop computers. Fuel cells used as electric power plants may be successful before vehicular ones are. This is because a fuel cell produces electric power which is what is required in this case. In transportation applications the electricity produced must then be converted to mechanical power. It is unclear whether hydrogen fuel will be widely used. This is because solid oxide fuel cells will be become extremely popular and these can cleanly convert renewable hydrocarbon fuels. This paper reviews the advances and typical application of fuel cell comparison in terms of parameters like output, application and advantages.

Keywords: Fuel cell, Fuel, Hydrogen, Electrolyte, cathode, anode, Temperature,

I. INTRODUCTION

Fuel cells can promote energy diversity and a transition to renewable energy sources. Fuel cells run on hydrogen, the most abundant element on Earth. The great thing about fuel cells, is that they don't care where the hydrogen comes from - water, methanol, ethanol, natural gas, gasoline or diesel fuel, ammonia or sodium bore hydride. Fuels containing hydrogen generally require a "fuel reformer" that extracts the hydrogen. Energy also could be supplied by biomass, wind, solar power or other renewable sources. Fuel cells today are running on many different fuels, even gas from landfills and wastewater treatment plants.

When using a fuel other than pure hydrogen, a reformer or fuel processor is required. A reformer a device that produces hydrogen from fuels such as gasoline, methanol, ethanol or naphtha. Three basic reformer designs are being evaluated for fuel cells for use in vehicles steam reforming, partial oxidation and auto-thermal reforming. Steam reformers combine fuel with steam and heat to produce hydrogen. The heat required to operate the system is obtained by burning fuel or excess hydrogen from the outlet of the fuel cell stack. Partial oxidation reformers combine fuel with oxygen to produce hydrogen and carbon monoxide. The carbon monoxide then reacts with steam to produce more hydrogen. Partial oxidation releases heat, which is captured and used elsewhere in the system. Auto-thermal reformers combine the fuel with both steam and oxygen so that the reaction is in heat balance. Auto-thermal reforming, while not as fully developed as the others, offers the most flexibility in heat management. In general, both methanol and gasoline can be used in any of the three reformer designs. Differences in the chemi re of the fuels, however, can favor one design over another.

II. BASIC OF FUEL CELL

Fuel cells convert the chemical energy of fuels directly into electricity. The principle of the fuel cell was developed by William Grove in 1839. Already around 1900 scientists and engineers were predicting that fuel cells would be common for producing electricity and motive power within a few years. That was roughly 100 years ago. Still development length has little to do with whether technology will be eventually successful. Fuel cells are in into commercial reality.

There have been several world events that have shaped how we think about energy technology. The Chernobyl disaster made the world think differently about nuclear fission power. After many years of developing fusion power many scientists are not sure it will happen. The cheap nuclear solution therefore is not a reality right now. The new focus instead is for efficient and clean technology that uses fuel. This focus may only last as long as abundant fuel is available, but it is the focus now. Just around the corner fusion power may be developed. Costs of solar panels may be brought to the point where all electricity is generated with solar energy.

III. WORKING OF FUEL CELL

A fuel cell works similar to a battery. In a battery there are two electrodes which are separated by an electrolyte. At least one of the electrodes is generally made of a solid metal. This metal is converted to another chemical compound during the production of electricity in the battery. The energy that the battery can produce in one cycle is limited by the amount of this solid metal that can be converted. In the fuel cell the solid metal is replaced by an electrode that is not consumed and a fuel that continuously replenishes the fuel cell. This fuel reacts with an oxidant such as oxygen from the other electrode. A fuel cell can produce electricity as long as more fuel and oxidant is pumped through it.

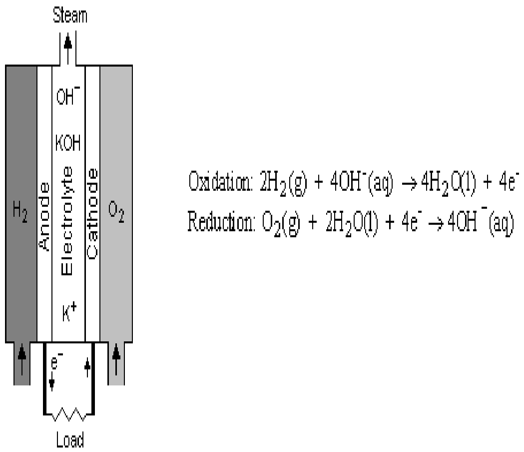

Figure 1. Alkaline fuel cell often uses hydrogen and oxygen as fuel

The alkaline fuel cell as shown in Fig 1 is one of the oldest and most simple type of fuel cell. This is the type of fuel cell that has been used in space missions for some time. Hydrogen and oxygen are commonly used as the fuel and oxidant. The electrodes are made of porous carbon plates which are laced with a catalyst which is a substance that accelerates chemical reactions. The electrolyte is potassium hydroxide. At the anode, the hydrogen gas combines with hydroxide ions to produce water vapor. This reaction results in electrons that are left over. These electrons are forced out of the anode and produce the electric current. At the cathode, oxygen and water plus returning electrons from the circuit form hydroxide ions which are again recycled back to the anode. The basic core of the fuel cell consisting of the manifolds, anode, cathode and electrolyte is generally called the stack.

IV. TYPES OF FUEL CELL

There are numerous types of fuel cells that have been made. The most common are shown below.

Solid Oxide Fuel Cell (Sofc)

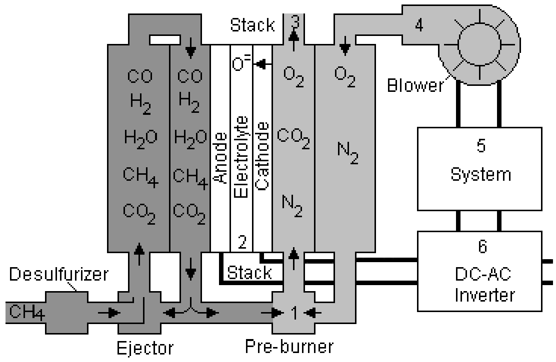

Figure 2.

The Solid Oxide Fuel Cell is considered to be the most desirable fuel cell for generating electricity from hydrocarbon fuels. This is because it is efficient simple, highly, tolerant to impurities, and can at least partially internally reform hydrocarbon fuels.

The SOFC runs at a red-hot temperature near 700-1000°C. One of the big advantages of the SOFC over the MCFC is that the electrolyte is a solid. This means that no pumps are required to circulate hot electrolyte. Small planar SOFC of 1 kw could be constructed with very thin sheets and result in a very compact package.

A big advantage of the SOFC is that both hydrogen and carbon monoxide are used in the cell. In the PEFC the carbon monoxide is a poison, while in the SOFC it is a fuel. This means that the SOFC can readily and safely use many common hydrocarbons fuels such as natural gas, diesel, gasoline, alcohol and coal gas. Because the chemical reactions in the SOFC are good at the high operating temperatures, air compression is not required. Especially on smaller systems this results in a simpler system, quiet operation, and high efficiencies.

In fact insulation must be used to maintain the cell temperature on small systems. The cell is cooled internally by the reforming action of the fuel and by the cool outside air that is drawn into the fuel cell.

Direct Alcohol Fuelcell (Dafc)

Electrolyte is a polymer or a liquid alkaline. This type of fuel cell was largely overlooked in the early 1990s because its efficiency was below 25%. Most companies rather pursued the PEFC because of its higher efficiency and power density. It is expected that the DMFC will be more efficient than the PEFC for automobiles that use methanol as fuel. Presently the power density of the DEFC is only 50% of the DMFC but hopefully this can be improved in future.

Fuel crossing over from the anode to the cathode without producing electricity is one problem that has restricted this technology from its inception. There are already working DMFC prototypes used by the military for powering electronic equipment in the field.

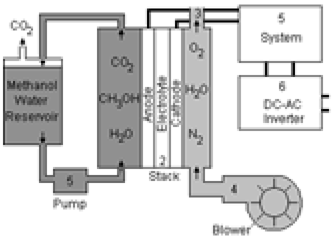

Figure 3.

Figure 3 illustrates a type of DMFC that could be used in a 30 kw system. Even smaller ones for use as battery replacements do away with the air blower and the separate methanol water tank and pump. Such fuel cells are not much different than batteries in construction.

Recently there has been much concern about the poisonous aspects of methanol--methyl alcohol. As of 2001 methanol is "out" and ethanol is "in". Already several companies are now working on DEFC. Presently the power density is only 50% of the DMFC but hopefully this can be improved.

Polymer Electrolyte Fuel Cell (Pefc)

The PEFC is considered the darling fuel cell by proponents of the hydrogen economy. Automobiles emitting pure water from their tailpipes are envisioned. It is not likely that there will be hydrogen pipelines supplying homes, businesses and service stations in the near future however. Many companies are proposing that PEFC systems would extract hydrogen from hydrocarbon fuels such as methanol or natural gas. While the efficiency of the PEFC when running on hydrogen and no air pressurization is high, practical systems that use fuel reforming and air compression suffer in efficiency. Small 30 kW AC power plants will likely be 35% fuel to electricity efficient, 200 kW units 40% and large units 45%. An automobile power plant including an electric motor would have an efficiency of about 35%. There has been some progress made in storing hydrogen in different materials such as hydrides or carbon. If such materials can be perfected this would dramatically increase the chances for the PEFC success for automotive applications The PEFC generally operates at 80°C which makes it ideal for small applications and allows reasonably inexpensive materials to be used. A catalyst is also required to promote the chemical reaction at the low temperatures involved. Previously the platinum catalysts used in the stack made this type of fuel cell expensive

Phosphoric Acid Fuel Cell (Pafc)

The Phosphoric Acid Fuel Cell has been under development for 15 years as an electric power plant. While it has a lower real efficiency than the MCFC or SOFC, its lower operating temperature of 160-220°C was considered more ideal for small and midsize power plants. Midsize 200 kW AC power plants are 40% efficient and large 11MW units are 45% efficient when running on natural gas. These efficiencies are comparable to the PEFC.

Molten Carbonate Fuel Cell (Mcfc)

The Molten Carbonate Fuel Cell has also been under development for 15 years as an electric power plant. The operating temperature of 600-650°C is lower than the SOFC. It is considerably more efficient that the PAFC. It already has the advantage of reforming inside the stack. Its disadvantage is the corrosiveness of the molten carbonate electrolyte. Large AC power Plants using gas turbine bottoming cycles to extract the waste heat from the stack could be up to 60% efficient when operating on natural gas. When problems with the SOFC are solved, work on the MCFC may be disbanded.

V. FUTURE FUELS

The hydrogen economy which was popularized in the 1970s was based on producing hydrogen using nuclear power Plants Now that nuclear power is unpopular, we have eliminated any present method of making large amounts of hydrogen for a reasonable price. Society has however held on to the wonders of having a hydrogen economy, where hydrogen would be used for everything from generating electric power to heating homes and powering industry.

Hydrogen is admittedly a wonderful fuel because only water is produced in operating the fuel cell. Hydrogen is however a difficult fuel to store. It is difficult and costly to liquefy. It has lower energy content than natural gas when pressurized in tanks. There has been increasing success in storing hydrogen gas in metal hydrides and carbon compounds but many of these techniques require either pressure or temperature swings during storage and extraction. Many more require cryogenic refrigeration.

There is presently no way of making cheap hydrogen. Laws of energy demand an equal or larger amount of another form of energy to produce it. Presently hydrogen is mostly made from natural gas. Producing hydrogen by electrolysis is generally even less efficient because the electricity is generated by a gas turbine which is no more than 57 % efficient.

The hydrogen would be made from the electricity produced by solar panels or fusion power Plants, the situation would be somewhat different. Presently however the cost of making hydrogen from the electricity of solar panels is much higher than making it from natural gas. As well electricity is presently sold for about 3x the cost of fuel--which makes selling electricity more viable than producing hydrogen. Fusion power has not been perfected presently.

The carbon dioxide quickly mixes throughout the globe. There are benefits in using renewable hydrocarbon fuels rather than hydrogen.

Ethanol is presently viewed by many scientists as the perfect fuel for portable fuel cells. Methanol and ethanol presently can be made from either natural gas or biomass. This process is also about 65% efficient. Therefore hydrogen and alcohol cost about the same to produce and store. The DMFC however is slightly less efficient than a PEFC operating on stored hydrogen gas. Many consider that the benefits of storing a liquid fuel more than offset this loss of efficiency. In the future it may also be possible to produce alcohol directly in solar panels or in fusion power plant.

VI. COMPARISON OF FUEL CELL TECHNOLOGIES

Fuel Cell Type	Common Electrolyte	Operating Temperature	System Output	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)*	Solid organic polymer poly-perfluorosulfonic acid	50 - 100°C 122 - 212°F	<1kW – 250kW	50-60% electric	• Back-up power • Portable power • Small distributed generation • Transportation	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Requires expensive catalysts • High sensitivity to fuel impurities • Low temperature waste heat
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90 - 100°C 194 - 212°F	10kW – 100kW	60-70% electric	• Military • Space	• Cathode reaction faster in alkaline electrolyte so high performance	• Expensive removal of CO_2 from fuel and air streams required
Phosphoric Acid (PAFC)	Liquid phosphoric acid soaked in a	150 - 200°C 302 - 392°F	50kW – 1MW (250kW	80 to 85% overall with combined	• Distributed-ed	• High efficiency • Increased	• Requires platinum catalysts

	matrix		module typical)	heat and power (CHP (36-42% electric)	generation	tolerance to impurities in hydrogen • Suitable for CHP	• Low current and power • Large size/weight
Molten Carbonate (MCFC)	Liquid solution of lithium, sodium, and/or potassium carbonates, soaked in a matrix	600 - 700°C 1112 - 1292°F	<1kW – 1MW (250kW module typical)	85% overall with CHP (60% electric)	• Electric utility • Large distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP	• High temperature speeds corrosion and breakdown of cell components • Complex electrolyte management • Slow start-up
Solid Oxide (SOFC)	Solid zirconium oxide to which a small amount of yttira is added	650 - 1000°C 1202 - 1832°F	5kW – 3MW	85% overall with CHP (60% electric)	• Auxiliary power • Electric utility • Large distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte reduces electrolyte.	• High temperature enhances corrosion and breakdown of cell components • Slow start-up

VII. CONCLUSION

Fuel cells are still a few years away from commercialization on a large scale. It is very difficult to tell which fuel and which technology will be predominant in the future. This work depicts the overall performance of all fuel cell in terms of different parameters with their applications. There are some problems to be solved in the solid oxide fuel cell and the direct alcohol fuel cell.

If these can be solved then these will become the predominant fuel cells being developed in the future and commercialization of fuel cell is not far from today.

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