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SURVEY ON DEVELOPMENT IN SOLID-OXIDE FUEL CELLS (SOFC)

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Abstract:- **In this paper particular, attention is given to the design and operation of Solid Oxide Fuel Cells (SOFCs). Moreover, advantages of SOFCs with respect to the other fuel cell technologies are identified. This paper also reviews the limitations and the benefits of SOFCs in relationship with energy, environment and sustainable development. A solid oxide fuel cell (SOFC) is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. Fuel cells are characterized by their electrolyte material; the SOFC has a solid oxide or ceramic, electrolyte. Advantages of this class of fuel cells include high efficiency, long-term stability, fuel flexibility, low emissions, and relatively low cost.**

Keywords:- *lanthanum manganite ($LaMnO_3$), nickel-zirconia cermet, yttria stabilized zirconia*.

I INTRODUCTION

Fuel cells are electrochemical cells.In a fuel cell electrical energy is obtained from oxygen and a fuel that can be oxidized
The essential process in a fuel cell is

Fuel + Oxygen → Oxidation product +Electricity

Hydrogen-0xygen fuel cell, Solid oxide fuel cell are the examples of fuel cells. Solid oxide fuel cells (SOFCs) are a class of device which makes conversion of electrochemical fuel to electricity with negligible pollution.

A solid oxide fuel cell, which comprises an assembly of a plurality of unit cells each comprising a solid electrolyte, and a fuel electrode and an air electrode provided on both sides of the solid electrolyte, respectively, the fuel electrode being composed mainly of ruthenium, nickel and ceramics can perform power generation of high efficiency with hydrocarbon or hydrogen resulting from complete reforming of hydrocarbon, or a steam-reformed gas containing carbon monoxide as the main component as a fuel gas.

1. *Solid Oxide Fuel Cell*

In these cells, a solid electrolyte eg mixture of yttrium dioxide and zirconium dioxide is used The cells operate at a temperature of about 1000^0C. Charge transfer in the electrolyte is done by oxygen ions. The anodes are made of nickel/zirconium oxide cermet whereas; the cathodes are made of lanthanium manganate ($LaMnO_3$). Reforming gases (H_2 + CO) are used as fuel and oxygen is used as oxidant. Since the cathode reaction use only oxygen (or air) as oxidant re-circulation of carbon-dioxide from the anode exhaust is not needed. The reaction rate is enhanced because at the high operating temperature (about 1000^0C) and noble metal catalysts are not required. Carbon monoxide does not poison the electrodes and indeed is also used as a fuel. Internal fuel reforming is possible. Since only solid electrolyte is used, the problem associated with liquid handling and corrosion is avoided. Solid oxide fuel cells differs in many respects from other fuel cell technology First they are composed of all solid state materials. The anode, cathode and electrolyte are all made from ceramic substance. Second because of all ceramic make up, the cells can operate at temperatures as high as 1000^0C. Significantly better than any other major category of fuel cells. This produces exhaust gases at temperatures indeed for co-generation applications for use in combined cycle electric power plants. Third, the cells can be categorized either as rolled tubes or as flat plates and manufactured using many of the technologies now employed today by the electronics industry.

2. *Cathode*

The typical material for the cathode is strontium-doped lanthanum manganite ($LaMnO_3$), because of its good electrochemical activity for oxygen reduction, high electronic conductivity, and good stability. Other materials, like platinum and other noble metals have also been considered. However, considering the high cost of platinum, it is not best choice to use this metal as the cathode.

3. *Anode*

Though as for the cathode, precious metals like platinum can be used for the SOFC anode, the most widely used material is a nickel-zirconia cermet, i.e. a mixture of nickel and yttria-stabilised zirconia (YSZ) skeleton. Nickel plays the role as the electro catalyst for anode reaction and also can conduct the electrons produced at the anode while the yttria-stabilised zirconia is used for conducting oxygen ions.

4. *Electrolyte*

For the SOFC electrolyte, yttria stabilized zirconia (YSZ), i.e. zirconia doped with around 8 mol％ yttria and gadolinia-doped ceria (GDC) is the most widely used materials suitable for the SOFC electrolyte. GDC has very good ionic conductivity, but it also shows a high electronic conductivity. Compared with GDC, YSZ is stable in either reducing or oxidizing environments and has a good conductivity to transmit ions, especially at sufficiently high temperature. But unlike GDC, YSZ shows little or no capability to conduct electrons. For solid oxide electrolyte, the most common to date has been yttria stabilized zirconia (YSZ)) formed as a crystal lattice. The hard ceramic electrolyte is coated on both sides with specialized porous electrode membrane. At the high operating temperatures, oxygen ions are formed at the air electrode (the cathode). When a fuel gas containing hydrogen is passed over the fuel electrode (the anode), the oxygen ions migrate through the crystal lattice to oxidize the fuel. Electrons generated at the anode move out through external circuit resulting electricity. Reforming natural gas or water gas (H_2 + CO) or other hydrocarbon fuel to extract the necessary hydrogen can be accomplished within the fuel cell eliminating need for an external reformer. In such a fuel cell, reformat gas (H_2 + CO) is used as a fuel and oxygen as a oxidant.

The electrode reaction can be summarized as follows

Anode reaction -: $xH_2 + yCO + (x+y)O^{2-} \rightarrow xH_2O + yCO_2 + 2(x+y)e^-$

Cathode reaction -: $1/2(x+y)O_2 + 2(x+y)e^- \rightarrow (x+y)O^{2-}$

Net reaction -: $1/2(x+y)O_2 + xH_2 + yCO \rightarrow xH_2O + yCO_2$

The essential features of solid oxide fuel cell are shown in figure 1**.**

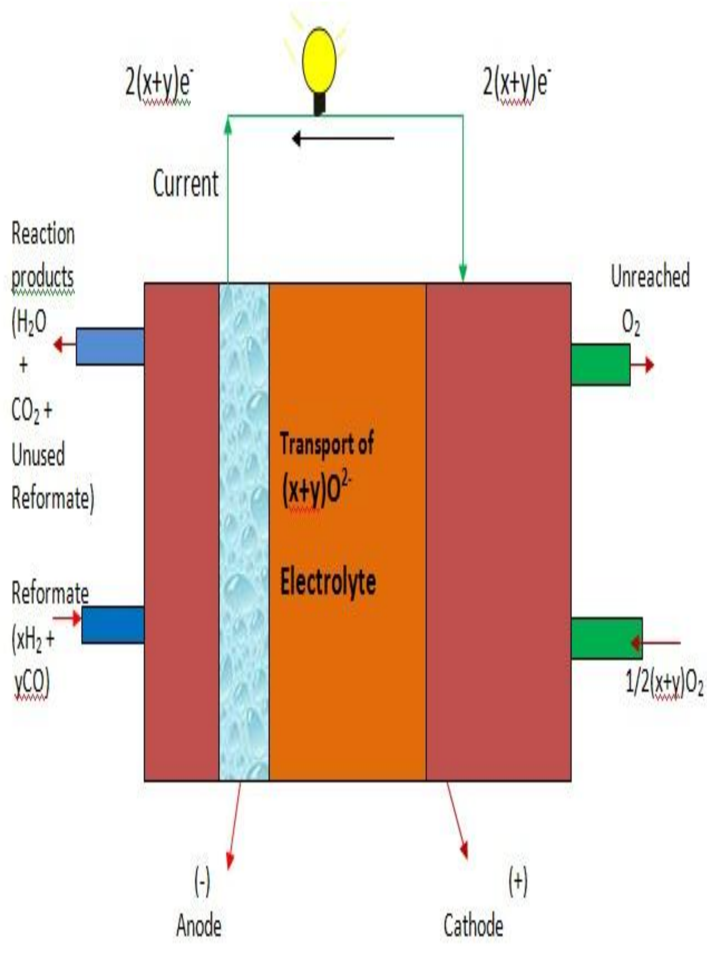

Figure 1 Solid-Oxide Fuel Cell (SOFC)

The reaction rate at high operating temperature (1000^0C) is quite high so no noble metal catalyst is required. Moreover, carbon-monoxide does not poison the electrodes. The fuel to electricity efficiencies of solid oxide fuel cell is expected to be around 50% If the hot exhaust of the cell is used in a hybrid combination with gas turbines, the electrical generating efficiency is likely to approach 60%. In applications designed to capture and utilize the systems waste heat, overall fuel use efficiencies could top 80-85%.

Cell Voltage = 0.81V – 1.1V.

(Calcified power) Qualified power (W) = 10 W - 1 kW

Some R and D efforts are made to design medium temperature solid oxide fuel cells. The cells tested are Hydrogen-Oxygen cells. The solid material used is hydrogen-exchanged β alumina. The operating temperature of this type of solid-proton conductor is in the range of 150-200^0C.

II TUBULAR SOLID OXIDE FUEL CELL TECHNOLOGY

A solid oxide fuel cell (SOFC) is an electrochemical device that converts hydrogen and carbon monoxide from hydrocarbon fuels into electricity. The process is driven by the flow of oxygen ions from a cathode to an anode through an electrolyte. When these ions combine with hydrogen and carbon monoxide from the fuel, electrons are released to an external circuit. This process is replicated many times in the fuel cell, in arrays or stacks, and it results in highly efficient power generation with virtually no greenhouse gas emissions.

In contrast to planar or membrane designs, tubular solid oxide fuel cells are constructed from many discreet electrolytic tubes in parallel. The anodes are on the inside of each tube and the cathodes are on the outside, in an “anode supported” configuration,

Using the exclusive “fuel-in-the-tube” technology, fuel is introduced directly inside the tubes in a high-temperature environment, at approximately 750 ^{0}C. Ambient air (the oxygen source) circulates around the outside of the tubes. The oxygen ions are conducted through the tube, and an electrical potential is generated between the inside and outside of the tube. This potential difference is tapped as electrical energy. The electrochemical process happens in multiple tubes in a stack, producing power systems that can supply a few hundred watts to 10 kilowatts.

The net result is a highly efficient system that produces clean electricity, with water, heat, and low levels of carbon dioxide as the only by-products. Efficiency is further enhanced when the high-grade waste heat is recovered for heating, hot water and processing purposes. This results in total fuel efficiency (LHV) levels exceeding 80 percent for residential and industrial cogeneration applications.

Because operation is below the high temperature of internal combustion engines or turbines, fuel cells have nearly undetectable levels of nitrous oxides (NOx). Sulfur oxides (SOx) are reduced due to the high efficiency of fuel cells that also provide near-silent operation and none of the maintenance.

SOFC Advantages:

SOFCs have a number of advantages Due to their solid materials and high operating temperature

1. Since all the components are solid, as a result, there is no need for electrolyte loss maintenance and also electrode corrosion is eliminated.

2. Since SOFCs are operated at high temperature, expensive catalysts such as platinum or ruthenium are totally avoided
3. Also because of high-temperature operation, the SOFC has a better ability to tolerate the presence of impurities.
4. Costs are reduced for internal reforming of natural gas.
5. Due to high-quality waste heat for cogeneration applications and low activation losses, the efficiency for electricity production is greater than 50% and even possible to reach 65% .
6. Releasing negligible pollution is also a commendable reason why SOFCs are popular today. High efficiency and fuel adaptability are not the only advantages of solid oxide fuel cells. SOFCs are attractive as energy sources because they are clean, reliable, and almost entirely nonpolluting. Because there are no moving parts and the cells are therefore vibration-free, the noise pollution associated with power generation is also eliminated.

SOFCs Disadvantages :
1. SOFCs operate at high temperature, so the materials used as components are thermally challenged.
2. This relatively high cost and complex fabrication are also significant problems that need to be solved.

III SOFC APPLICATIONS

Due to the advantages mentioned above, SOFCs are being considered for a wide range of applications, such as working as power systems for trains, ships and vehicles; supplying electrical power for residential or industrial utility

IV CONCLUSION

1. The cell voltage of SOFC = 0.81V
2. In applications designed to capture and utilize the systems waste heat, overall fuel use efficiencies could top 80-85%.
3. Attention is given to the design and operation of Solid Oxide Fuel Cells (SOFCs).

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