An analysis of fuel cell technologies engineering essay

Engineering

Production of Electrical power without causing damage to our environment is an ongoing challenge. The identified eco friendly energy alternatives such as solar, wind, hydroelectric and geothermal power can only be used in particular environments. Therefore identifying an energy source capable of working in most environments is essential. Fuel cells fit in here. They are quiet and efficient, produce almost no pollution and can work in difficult environments. Hydrogen is high in energy content. A fuel cell essentially combines hydrogen and oxygen to produce electricity, heat, and water. It is an electrochemical engine without any moving components. Major components of fuel cell consist of catalytically activated electrodes for the fuel (anode) and the oxidant (cathode) and an electrolyte conducting ions between the electrodes. Reactants flow into the cell while the reaction products flow out. The electrolyte remains within the cell. Fuel cells work continuously till the reactant and oxidant supplies continue. The source of Hydrogen can be from different sources depending on the application. For example, Hydrogen can be separated by reforming hydrocarbons from natural gas. Three types which are used in most applications are proton-exchange-membrane fuel cells (PEMFCs), regenerative fuel cell (RFC) systems, and solid-oxide fuel cells (SOFCs). PEMFCs use hydrogen fuel and by product is only water. RFC systems use hydrogen and oxygen to produce electricity, water, and heat. An electrolyzer can be used to break the water into hydrogen and oxygen which can be reusedSOFCs are principally used in power generation and are highly efficient. They are also being developed for portable electronic devices, cars, and aircraft. In short, Fuel cells are very important and their applications are likely to be in varied areas ranging from, Portables to Automobiles. The other major area of application will be in Stationary Power generating stations. FUEL CELL BASICSA fuel cell uses Hydrogen and Oxygen to create electricity by means of an electrolytic process. This means fuel`s chemical energy is directly converted into Electrical energy and with high efficiency. Since they are combined by an electrochemical reaction & not burnt, efficiency is high. Several steps of conventional systems via Extraction and conversion heat to Mechanical energy and finally to electrical energy are nonexistent. After combination of hydrogen and water to produce energy, the only by-product let out is water and thus the entire process is non-polluting. It is one of the most exciting emerging fields in Renewable energy. No greenhouse gases are emitted. Fuel cells are unique in the sense they can be used for powering small gadgets like laptops to large stationary power generating units to Automobiles. WORKINGA fuel cell comprises of two thin electrodes, an anode, a cathode and electrolyte which is sandwiched between the electrodes. Hydrogen fuel is fed to anode and oxygen to cathode. With a catalyst, Hydrogen separates as Electrons (negatively charged) and Protons (Positively charged ions). Electrons migrate externally and create Electricity. This is used before it reaches Cathode. Protons meanwhile go through electrolyte, reunite with Oxygen and the electrons. This produces Heat and water. However incase of Polymer exchange membrane (PEM) and Solid Oxide cells, alkaline and molten carbonate the movement is different. Though the function appears very similar to a conventional battery, in the fuel cell, electrodes are not consumed whereas metal electrode is consumed in the former. APPLICATIONSThis ranges from Mobile uses such as transportation, Stationary power generation for distribution and for portable items like Laptops etc. FUEL CELL SYSTEM CONSTITUENTSThe four major components of a Fuel system comprise of a fuel Processor, Stack, Current converter & conditioner and finally a heat recovery system. The other smaller sub components which are part of the package are to control, temperature, humidity, pressure and waste water.�FUEL CELL STACKAll actions take place in Fuel cell stack. Energy is converted here. DC current is produced here as an outcome of the chemical reaction. Since a single cell produces very little energy, Hundreds of fuel cells are connected and constitute a Stack. The output power depends on size, temperature of operation, type etc.�FUEL PROCESSORThe fuel is converted by the processor into a form useable by the fuel cell. If hydrogen is fed into the cell, a processor might not be required. If needed to filter out impurities from Hydrogen then it can be considered. However if the system uses hydrogen-rich fuel like methanol, gasoline etc. a reformer is required to convert hydrocarbons into a gas mixture of hydrogen and carbon compounds and is known as " reformate." In most cases, the reformate is sent to another reactor in order to remove impurities like carbon oxide. Afterwards it is returned back to cell stack. Thus impurities in the gas are prevented from binding with catalysts. This binding is called " poisoning" and it reduces efficiency and life of the cell. However molten carbonate and solid oxide fuel cells operate at high temperatures and fuel is reformed in the cell itself and is called as internal reforming. However they need trap to isolate impurities from the unreformed fuel. Both internal and external reforming releases carbon dioxide, but very less than the conventional systems.�CURRENT

INVERTERS AND CONDITIONERSThe purpose of Current inverters and conditioners is to adapt the electrical current from the fuel cell to suit the needs of the electrical application. Direct Current (DC) is produced from Fuel cells which is a unidirectional flow. Therefore, the direct current needs to be converted to alternating current (AC), besides both need to be conditioned too. This conditioning results in loss of efficiency anywhere between 2-6 %.�HEAT RECOVERY SYSTEMFuel cell systems generate heat which can be considered as a by-product. Those cells that work at high temperatures via solid oxide and molten carbonate systems � this surplus heat energy generated can be used to produce steam or used to produce electricity using a gas turbine or any other suitable device. Thus the overall system efficiency can be improved. TYPES OF FUEL CELLSThe primary classifications of Fuel cells are based on the electrolyte that they use. This influences the kind of chemical reactions that take place in the cell, the kind of catalysts required, the temperature range of the fuel cell, the type of fuel required, and other factors. These characteristics, determines the applications of the fuel cell. There are many types of fuel cells currently under development. (1) Most familiar ones areoPolymer Electrolyte Membrane (PEM) Fuel CellsThe Polymer Electrolyte Membrane or the Proton Exchange Membrane Fuel Cell (PEMFC) is one of the most elegant types of fuel cells with respect to design and mode of operation. (2) These types use a solid polymeric membrane as its electrolyte. This is sandwiched between two porous carbon electrodes containing a platinum catalyst. The primary fuel used in this type is pure hydrogen and oxygen from the air. (1) The PEMFC are low temperature Fuel Cells and can be used in stationary power production and light duty vehicles

(3). The operating temperature is 80-120�C (4). Also these types of Fuel Cells cover a wide range of power levels which is a great advantage. (2)oDirect Methanol Fuel Cells (DMFC)It is one of the newly developed Fuel Cell. As the name suggests, the fuel used in DMFCs are pure methanol. The methanol is mixed with steam and directly is fed to the anode of the fuel cell (1). As methanol has a higher energy density than hydrogen, DMFCs does not have much fuel storage problem (1). These types of fuel cells also use proton exchange membrane as its electrolyte. A reformer is not needed for a DMFC as the catalyst draws hydrogen directly from the liquid methanol (3). The operating temperature of DMFC is 50 � 120�C. These are low temperature fuel cells and are used in mobile phones and laptops. The efficiency of these fuel cells is around 50% (4). oAlkaline Fuel Cells (AFC)This fuel cell is one of the foremost fuel cell technologies that were developed. These are high temperature fuel cells with temperature range of 100-250� C (5). The AFCs use alkaline electrolyte, usually Potassium Hydroxide (KOH), sandwiched between the two electrodes. These fuel cells were widely used in the US space program to produce energy and water on-board. As cathode reaction is faster in alkaline electrolyte, it leads to better performance of the fuel cell. Also these types of fuel cell can use variety of catalysts which are inexpensive (6). The main drawback of AFCs is that, they can easily be poisoned by carbon dioxide. Even small traces of CO2 can affect the cells performance. So, thorough purification of the fuel should be done before using it which is expensive (7). The AFCs are used in Military and Space programs for power and water (6). oPhosphoric Acid Fuel Cells (PAFC)The phosphoric acid fuel cell (PAFC) is regarded the " first generation" of modern fuel cells (1). Also this fuel cell is the first to be used commercially. As the name suggests, the PAFC uses liquid Phosphoric acid soaked in a Teflon-bonded silicon carbide matrix (1). These are intermediate temperature fuel cells with temperature range 150-220�C. PAFCs are 38 to 40% efficient when generating electricity and around 85% when used for combined heat and power (4). PAFCs are also less powerful when compared to other fuel cells and therefore are typically large and heavy. They are also expensive as they use platinum as their catalyst (1). They are normally used for stationary power generation, but some cells have been used to power large vehicles (8). oMolten Carbonate Fuel Cells (MCFC)These are high temperature fuel cells and hence do not require any external reformers. These are capable of direct utilisation of natural gas and coal derived gases for electrical and thermal utility (2). �The electrolyte used in MCFCs is of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminium oxide (LiAlO2) matrix� (1). These are high temperature fuel cells with operating temperature of about 600-700�C and with electrical efficiency of 45-47%. When used in combined heat and power the efficiency goes upto 85% (6). Any non precious metal catalyst can be used in MCFCs. The main drawback of this type is the durability and life as the electrolyte is corrosive in nature (4). MCFCs can be can be used for electrical utility, industrial, and military applications (3). oSolid Oxide Fuel Cells (SOFC)Solid Oxide Fuel Cell is an all solid power system (2). It has a very high operating temperature of 600-1000�C and does not require any precious metal catalyst. The electrolyte used is Yttria Stabilised Zirconia which is a hard, non porous ceramic compound (4). The electrical efficiency of SOFC is around 50-

60% but the combined heat and power efficiency is around 85% (8). These are used in high-powered applications, such as industrial uses or central electricity generation stations (3). The main drawback of this fuel cell is the slow start up as it has high operating temperature (8) and sealing issues (4). COMPARISON OF FUEL CELL TECHNOLOGIESFuel Cell Designation Electrolyte Temperature �C Cell Efficiency Type of ApplicationAlkaline Fuel Cell AFC Aqueous KOH 100 - 250 60 - 70% Military, SpaceProton Exchange Membrane Fuel Cell PEMFC Polymer electrolyteMembrane 80 - 120 50 � 60% Back-up power, Portable power, Small distributed generation, TransportationDirect Methanol Fuel Cell DMFC 50 - 120 50% Mobile , LaptopsPhosphoric Acid Fuel Cell PAFC H3P04 150 - 220 80 - 85% CHP36 - 42% electricStationary, Light duty vehiclesMolten Carbonate Fuel Cell MCFC Alkaline carbonates 600 � 700 85% CHP45 � 47% electric Industrial, MilitarySolid Oxide Fuel Cell SOFC Yttria Stabilised Zirconia600 - 1000 85% CHP50 - 60% electricIndustrial, Central Power generationPARTS OF A FUEL CELLThe current focus being Automobiles, Polymer electrolyte membrane (PEM) fuel cells are considered the most apt for this application. Made from three layers of different materials namely1. Membrane electrode assembly2. Catalyst3. HardwareOther layers are designed to draw fuel and air and to conduct electrical current in the cell.? Membrane Electrode AssemblyMembrane electrode assembly (MEA) consists of the electrodes, polymer Electrode membrane and the catalyst. Anode: The anode has several functions. The electrons freed from the hydrogen molecules are allowed to move in an external circuit. Etched Channels in the anode disperse the hydrogen gas on the surface of the catalyst. Cathode: The cathode, contains channels to distribute oxygen on the surface of catalyst. It conducts the electrons from the external circuit to the catalyst, combine back with the hydrogen ions and oxygen and form water. Polymer electrolyte membrane: The polymer electrolyte membrane (PEM)�is a specially treated material which conducts only positively charged ions and blocks the electrons. The PEM is the most important component in the fuel cell. The thickness of the membrane varies with the type of membrane and the thickness of the catalyst depends on how much platinum (Pt) is used.? CatalystFuel cell, electrochemical reactions take place in two parts, Oxidation half-reaction at the anode and reduction half-reaction at the cathode. These two half-reactions progress very slowly at the low temperature of the PEM fuel cell. To hasten the reaction, electrodes are coated with a catalyst. Platinum powder is most commonly used and coated. This catalyst coating has to offer maximum surface area to hydrogen or oxygen. This side the PEM.? HardwareThe other hardware consists of backing layers, flow fields, and current collectors. These are to ensure maximum flow of current from a membrane/electrode set. Two Backing layers are positioned, each next to the anode and cathode. These are made of a porous carbon paper or cloth. Carbon can conduct the electrons that leave the anode to enter cathode. Due to the porosity, effective diffusion takes place. The diffusing gas spreads as it penetrates the backing and the entire surface area of the catalyzed membrane is in contact with it. The selection of the right backing material ensures the optimum amount of water vapour to reach the membrane/electrode assembly and the membrane too is kept humidified. A Teflon coating on the backing layers ensures that clogging is avoided. A bipolar plate that typically serves as both flow field and current collector is mounted, pressing the outer surface of the Backing layer. The plates are made of�graphite or metals which are lightweight but strong, gas impermeable and electron conducting. Each Bipolar plate provides a gas " flow field." Channels which are etched on the side of the plate carry the reactant gas from entry to exits. The flow field in the plate is critical as to how gases spread across the active area of the membrane/electrode assembly. These plates also act as current collectors. With these components the PEM fuel cell is complete in all respects and addition of an external electrical load ensures flow of current through the device. FUEL CELL ECONOMICSThe shortcoming for commercialization of fuel cells today is cost. Fuel cells fall short on commercial expectation when compared to traditional energy sources, in spite of the technical advances. While hydrogen is abundant, difficulties in storage and distribution are overwhelming. Hydrogen economy, as it is called, due to the impact it�s going to create on the future, is very much dependent on the research output. While considerable progress has been made with governments and Industries are just beginning to see the results from the huge initiatives they have pumped into fuel cell research. ROI is still far away. The three major application areas, namely Portables, Stationeries and Mobiles (Auto mobiles), each offer a different type of challenge and a solution in any of the three areas is likely bring in huge effect on our economies and environment, for mankind is extremely dependant on the above three. Fuel cell technology for the auto industry and mini power plants are fairly advanced, Portable electronics manufacturers are close to commercialization of their products. For example, a direct methanol fuel cell for laptop computers has been demonstrated. In conclusion, the cost effective fuel cell availability is going to be critical in the fuel cell economics of the futureENVIRONMENTAL ASPECTSHydrogen fuel cells are looked upon as an environmentally-friendly alternative to fossil fuels. Molecular hydrogen when oxidised, only direct by-product is water during power generation. This means Fuel cells could substantially bring down pollution and greenhouse gases. However research shows that there are emissions which could greatly damage the ozone layer. This issue needs to be confirmed. Highly efficient production systems, storage and transportation of hydrogen should avoid these unwanted emissions. However researchers highlight that such a system is commercially unviable, and possibly around 10-20% of the hydrogen is likely to escape into the atmosphere. Once Fuel cells make rapid commercial inroads, this figure is likely to increase. When Hydrogen reaches the stratosphere it gets oxidised, cool it and create more clouds thus delaying breaking up of the polar vortex at both the poles. This means the holes in the ozone layer become bigger and long lasting. The estimate is that the additional hydrogen will result in a 5-8% rise in depletion of ozone in the North Pole and approximately 3 and 7% in the South Pole. What is not known the absorption of this excess hydrogen by soil. If it is more, the Ozone layer will be affected less. The other major issue to be researched is How Nanotechnology in Fuel cell will affect the Environment. Nanotechnology has contributed positively in fuel cell technology. It is highly effective in conversion of energy and losses are minimal. Beside Cost of production is likely to be brought down. If Nanoparticles escape into the environment, it causes concern because of following reasonsNanoparticles have high surface reactivity which could trigger new chemical reactions on the surface of Earth or in the atmosphere. They have ability to accumulate in the soil and water and possibly affect the food chain balance. Nanoparticles, since they are ultra fine, could adversely affect all living organisms. The risk of leakage during the manufacture, careless usage and disposal of fuel cells is always high. The Environmental impact, at this point of time looks to be containable since most of the issues have been identified and necessary research is already on to address them. POLICYAll policy makers consider the need necessity to map and develop the pragmatic technology, business interest and science to achieve commercialisation of Fuel cell for the Hydrogen economy of the future. They understand that renewable hydrogen energy is critical in the scheme of future energy policy. The four horizontal policies for fuel cells and hydrogen are to be aimed at sustainable development, energy, transport and to the Lisbon Agenda for competitiveness, safety and growth. There are considerable overlaps in these categories, but clear demarcation will be essential in framing a policy frame workBesides there are very few International codes and standards which are to be written and incorporated so as to ensure Hydrogen economy grows with all safety standards in place. CONCLUSIONThe exciting solution which Hydrogen fuels are likely to offer for the future Energy requirement has made many governments and industries to pump in resources for its success. While there are concerns of Hydrogen leaking into atmosphere & also the heat which these cells are likely to create, one is confident that these issues will be taken care of. One main issue has been the use of Platinum and its availability in future. Scarcity is likely to increase the price of the metal. Effective recycling of platinum could be one solution. Several options like gold-palladium, iron and sulphur are being considered to bring down the costs as well as to increase the lifetime of the cells. High temperature fuel cells [Molten carbonate fuel cells (MCFC), and Solid Oxide Fuel cells (SOFC)] use Nickel and Nickel oxide, instead of Platinum. This is cost effective. Besides catalyst poisoning does not occur and high purity hydrogen is also not a requirement. Bipolar materials using nanocomposites are a low cost option. They are thermally stable and more efficient non-platinum electro-catalysts and will be available for use shortly. Similarly, hydrogen fuel cell technology that doesn�t require a catalyst using aluminium borane and water to generate the hydrogen is an interesting development. The biggest advantage in this process would be lower temperature whereby using in automobiles becomes a definite possibility. In conclusion, the current status of hydrogen Fuel cells is little above proof of concept. The challenge lies in Scaling up, Safety & Storage and it is definitely likely to happen in near future.