Oxidation of chemical reagents engineering essay

Engineering

FUEL CELL

INTRODUCTION

The fuel cell is the cell which converts the chemical energy of the fuel into electricity the process takes place with the help of oxidation of chemical reagents. In fuel cell mostly hydrogen is used as Fuel in some cases hydrocarbons is also used. The fuel cells are capable of supplying energy until the input is available. There are various types of fuel cells they are metal hydrate, electro galvanic, proton exchange membrane, alkaline, direct methanol and various other fuel cell is also available and when considering high temperature fuel cell there are two types one is solid oxide fuel cell (SOFC) and other is molten carbonate fuel cell (MCFC). Fuel cells are normally compared with batteries but actually it is different from batteries since this fuel cell technology does not require any recharging they just operate smoothly and efficiently by just using hydrogen and produces zero emission characteristic. Sometimes fuel cell is referred to thermal engines but there is a huge difference where thermal engines are restricted to Carnot efficiency but fuel cells are not [1]. Fuel cells are also used in various applications such as power generation, cogeneration, automobiles like cars, buses, forklifts, motorcycle, boats, submarine, airplane’s and many other applications. Due to its vast range of application, fuel cells are considered to be the most economic and marketable product in this present world. There are lot of research and development work is also being carried out in fuel cell for getting even better energy efficiency and lesser amount of environmental pollution. In considering fuel cell technology which is mainly focused on developing fuel cell hybrid vehicles (FCHV) due to the factor of minimal availability of fossil fuels. In order to sustain hydrogen based fuel cell which is considered to be the best alternative in all aspects and according to New European driving cycle (NEDC) this type of fuel cell vehicle is considered as less emission vehicle and fuel economy.[credit: Diego feroldi] Energy flow in fuel cell hybrid vehicle on a NEDC

PERFORMANCE AND EFFICIENCY CHARACTERISTICS

The performance characteristic of fuel cell is based on typical current/voltage curve (fig1). This characteristic is divided into three regions of polarization they are activation polarization, ohmic, concentration and other polarization losses [2]. image008. jpgFig 1 explains about the typical polarization between voltage/current densityThe electrical and heat generation rates are typically shown (fig 2) with the power density curve. image35. pngFig 2 which shows the waste heat generation and useful electric power generation rate density

REGION I ACTIVATION POLARIZATION

In this region the low current density loss is dominated and over potential of voltage is required for overcoming the activation energy on catalytic surface [2]. Ecell = E˚ (T, P) -ηa, a - | ηa, c|-ηr-ηm, a-| ηm, c|-ηxActivation polarizationThis above equation calculates the thermal equilibrium. The ηa, a and ηa, c indicate activation polarization of anode and cathode and normally this region represents voltage losses to initiate the reaction. In order to initiate a proper amount of polarization the electrical double layer method is induced to absorb the positive and negative charges it has two layers one is inner Helmholtz layer and the other is outer Helmholtz layer these layer which forms distinct activation losses in each of the electrodes. Therefore current transferred from anode to cathode will be equal in amount [2].| ia|=| ic|=| icell| The loss occurred in this region is considered to be nonlinear with current and therefore display a sharp primary drop in the cell voltage from open circuit condition and therefore increasing current through ohmic and concentration polarization. This reduces the remaining loss which occurred in this region [2]. The losses that occurred in this region are influenced by following factorsReaction mechanismCatalyst typeOperating parametersImpuritiesSpecies concentrationAgeService history [2]

KINETIC PERFORMANCE

When pure hydrogen fuel is operating, anode remains close to the theoretical potential of a hydrogen electrode. Kinetic performance are classified through butler volmer kinetics where it solves for the term of the overpotential and gives to the expression for the cell voltage [1]Ec= Er – b log10(i/i0) - irEr – represents the reversible potentiali0 – current density exchange for oxygen reductionb – tafel equationr – ohmic resistancei – current densitylimiting_current. gifButler Volmer modelThe cell voltage is described as the potential difference between anode and cathode where anode potential is assumed to 0V [2]. The tafel equation of slope is described through nature of electrochemical process where the slope is defined asb = RT/ nβF log10eTherefore during the open circuit condition there is no current flow or no net current through the circuit. When there is a net current flow then an over potential due to electrode reaction in each of the electrodes forces out the equilibrium condition towards the direction which is desired [2]. The simplified Butler volmer equation for the facile kinetics where high exchange current density and low current is appliedicell = io exp -αaF η -exp -αcF ηRu T Ru TThe linearized BV for low polarizationη = ±_i_ _Ru T____io (αa + αc)FHigh polarization, tafel expressionη = _Ru T_ ln (i/io)αj F

REGION II OHMIC POLARIZATION

Decrease in voltage is dominated by ohmic losses internally through the fuel cell [2]. The activation and concentration polarization are present in this region and this region is represented asηr = i AWhere, rk - represents value of specific area resistance of individual cellIn many types of fuel cell the operating life during the inception depends upon the ionic conductivity in main electrolyte and catalyst layers of ohmic polarization [2]. The electronic and ionic resistance is obtained through ohm's first law which isV= IR= iARThe factors governing ohmic loss in a fuel cell areMaterial conductivityMaterial thickness [2]The other major factor is contact resistance which should have the followingContact surfaceCompression pressureToleranceFlatness of fuel cell Bipolar plates [2]

REGION III CONCENTRATION POLARIZATION

The reduction in reactant surface can cause concentration polarization, which decrease the thermodynamic voltage from Nernst equation. During the reaction there will be some amount of consumption of fuel and oxidiser in electrode surface at a determined rate of faraday's law [2]. If the rate of transport of reactant is not equal then concentration polarization will occurṅconsumed = iA/nF ≤ ṅtransportThere are various reason for restricted transport rate they can be classified asGas phase diffusion limitationAccumulation of liquid phasePore blockageInert gas build upImpurity coverage due to blockage of surface [2]For operation of fuel cell with high temperature an raised pressure sometimes is considered since it minimises the oxygen mole fraction decrease with temperature for humidified flow. At the mass limiting current density the rate of mass transport is insufficient to further the consumption rate needed for reaction. Therefore the local concentration of reactant will be dropped down to zero which means the voltage of the cell becomes zero [2]. So, from Nernst equation at each electrode we getηm = -Ru T/ n F ln [1-i/il]The above can predict only the approximate loss due to concentration but in practice the loss varies more gradually, a semi empirical approach is used very often to determine the deviation by inducing a constant (B) therefore the equation becomesηm = -B ln[1-i/il]The total concentration polarization in a fuel cell is written asηm, a + ηm, c = -Ba ln [1-i/il, a] -Bc ln [1-i/il, c]This type of loss is almost in most of the electrode but there will be negligible anode loss for a hydrogen feed because of increased concentration and mass diffusion [2]. So, it represents the concentration polarization with single expression however the fuel cell polarization curve is determined by the limiting current density between the electrode [2].

THERMODYNAMIC EFFICIENCY

The fuel cell thermal efficiency depends upon the first law of thermodynamics and conserve energy [2]. The primary chemical bond available as reaction between enthalpy of product and reactants in a galvanic process which stored and converted to electrical energy and the major function of fuel cell is to convert the chemical energy to electrical energy therefore the thermodynamic efficiency isηth = actual electrical work / maximum available work [2]In a reversible process the maximum electrical work can be generic reversible system with electrical and mechanical work and constant temperature during the heat transfer therefore on substituting with first law of thermodynamics we get-dG = δWe [2]The above expression is for maximum electrical work from a system. The maximum conversion chemical to electrical energy in a fuel cell for reaction is related to change in Gibbs free energyMaximum highest voltage is calculated through the mechanical and electrical energy which is required to move a given charge. The electrochemical cell has a maximum reversible voltage which is described as-Δg/nF = E0 = -ΔG/nF [2]The above equation is mentioned for per mole fuel basis, this determines almost every fuel cell losses in maximum [2]. The F and n are constant for certain global redox reaction hence this forms the basis for Gibbs free energy such as temperature and pressure of a reactant and products [2]. Thermal voltage which is considered to be maximum for a reversible and adiabatic system because every real reaction process is related to entropy change of a system with voltage limit describing that all chemical energy is converted to electrochemical work without any heat transfer in the system [2]. For an ideal gas or liquid the enthalpy can be considered as temperature function, therefore the proportionality between the maximum expected voltage to thermal voltage describe the maximum electrical work to the potential electrical work, thermodynamic efficiency is written as [2]ηt, max = Maximum electrical workMaximum available work= ΔH- TΔSΔHTherefore the maximum thermodynamic efficiency for a fuel cell is can be expressed asηt, max = 1 - TΔ SΔH [2]

ADVANTAGES FUEL CELLS

There are lot benefits while considering fuel cell since it mainly uses hydrogen as a fuel which does not have any harmful effect on the environment but turns the energy into electricity and heat. The other major advantage are listed belowFuel cells which do not depend upon recharging as of batteries it supplies energy until there is a fuel input [3]. Fuel is cheap and readily available in a large amount since hydrogen which is present largely in the form of water [3]. The electricity produced in this type of technology is more when compared other source of technology. The efficiency of fuel cell is high therefore it is used even from small application to large automobile uses [3]. It can also use variety of catalyst in order accelerate the reaction in the fuel cellIt is best suitable to work in a real time operation of a system. The service life of fuel cell is quiet reliable [3].

DISADVANTAGES OF FUEL CELL

Though it is considered to be one of the best alternate sources for energy it has certain drawbacks while considering its manufacturing the major drawback of fuel is listed asThe production cost of the fuel cell is considered to be quiet very high [4]. Certain fuel cells like molten carbon (MCFC) and phosphoric acid (PCFC) are very huge for home and transportation application [3]Establishment of Durability and reliability in fuel cell is not made [5]. The hydrogen infrastructure is lacking in order to transport the hydrogen fuel from coast to coast [5]. PEM and Alkaline fuel cells convert hydrocarbons into hydrogen which will reduce the overall efficiency and deposit a small amount of pollution [6]. The onboard storage of fuel is quiet difficult though the research and development is being carried but still it is complicated [1]. In MCFC type high temperature corrosion occurs with low power density and long start up time [4]The hydrogen fuel cells are highly inflammable therefore it should always be maintained at an optimum operating condition [2]Apart from the expensive production cost and fuelling station should be set up around the countries using hydrogen fuel cell which is also expensive [5].

PRACTICAL ASPECTS OF INSTANCE PACKAGING, SAFETY, MANUFACTURING DIFFICULTIES

Considering the practical aspects the fuel cell for manufacturing requires more cost and investment since it is the developing technology and a substitute for other type of fuel operating technology. Currently for manufacturing a IC engine power plants requires a cost around £15-£25/KW and for fuel cell it is around £20/KW which is more for a competitive technology [4]. In order to meet the packing requirement the size and the weight of fuel cell has to be reduced it means not only the fuel cell stack but also the other ancillary components like fuel processor, expander, compressor, sensors therefore the power to weight ratio of the engine can be balanced. The major drawback in packaging of the fuel cell is the fuel cell stacking while considering the PEMFC which has become light and small but in spite of that it is still accompanying more space and weight due amount of fuel that has to be stacked and the cell stacking considered to be heart of fuel cell. The hydrogen storage in automotive application can be achieved through various methods such as [2]Compressed gasCryogenic liquidStorage of hydrideStorage of carbonStorage of liquid fuelSince in order use this competitive technology as a replacement for petrol or gasoline it has to have

5-10kg of hydrogen storage to achieve the fuel efficiency acquired in gasoline engines in automobiles. Therefore the above mentioned storage methods can help in acquiring this efficiency but it has many difficulties.

IN COMPRESSED HYDROGEN GAS

When comparing to gasoline engines it has less volumetric and gravimetric density of storage. The concern for safety is highly required due to high pressure cylinders and hydrogen combustibility. Refilling of the hydrogen tank from high pressure system is slow. Compression of hydrogen is a intensive process [2]

CYROGENIC LIQUID

It is another form of hydrogen storage which has many advantages such asStorage density of gravimetric and volumetric is highRefilling is very quick and easyTransportation from liquid hydrogen generation station is efficient [2]DIFFICULTIESSince it is a cryogenic fuel it can acquire heat from surroundings and can cause boil off loss therefore necessary high insulation has to be provided. Cost of preparing liquid fuel and energy loss is high. Safety concern is very much required while delivering of fuel [2].

HYDRIDE STORAGE SYSTEM

This system of storage can be considered as one of the safe methods of storing hydrogen because pressure reduction and heat application helps to extract hydrogen gas from the metal, therefore it can be used as fuel but the major drawback is the weight of metal hydride causes sustained vehicle operation, for example some alloys has a weight of up to 1250kg which can storage 15kg of hydrogen and thereby increasing the weight and reducing the fuel efficiency of the vehicle [2].

STORAGE OF LIQUID FUEL

Methanol which can also be used as a hydrogen carrier which is considered as non hydrogen liquid fuel, which helps in reducing the fuel storage volume but the main drawback, is it reduces the performance of the fuel cell [2].

SAFETY

For safety concerns in fuel cells the major things that are to be considered are electrical shocks and flammability of the fuel [7]. Generally the fuel cell vehicles are powered electrochemically through hydrogen gas and oxygen from the surrounded air into water and electrical energy. Since this electrical energy is used moving vehicle as well as to other appliances such radio, AC therefore the electricity generated is around 14V but after research and development in automobile industry they have increased standards up to 42V anything greater than 50V is potentially harmful and can even stop human heart therefore dangers with electric shocks are high while considering safety concerns [7]On the other hand the flammability of hydrogen fuel is also high because while storing hydrogen it is stored in many reforms and each has its own flammable characteristics therefore it should be maintained at normal temperature in a enclosed structure even a slightest of fuel leakage can be easily combusted [7].

MANUFACTURING CONCERNS

Even while making fuel cell the manufacturers face lot of difficulties with production, operating, development cost which is more when compared to normal IC engine because from safety till operation the fuel cell powered vehicles require utmost care otherwise it can create serious problem to manufacturer’s. Considering European market hydrogen powered fuel has the tendency of getting into sub zero temperature thereby it loses its durability and reliability though the manufacturers have many found ways for driving even at sub zero temperature, the performance of the vehicle is reduced and also the contaminants can settle down and degrade the fuel cells, so it is unknown at what level of intake of air and pure hydrogen is required to run an FCV in a real world conditions [8]. Apart from other factors the price of the vehicle is too expensive comparing other fuel operated vehicle therefore people will not be ready to afford for such high price alternate fuel technology [8].

WELL TO WHEEL FUEL CYCLE

The well to wheel analysis states that considering energy and emission from the process of getting raw materials till the motion of vehicle, this process can be carried out into two ways of analysis that is from well to tank and the other one is from tank to wheel [9].[credit : General motors analaysis 2001 study]

WELL TO TANK ANALYSIS

The basic material for well to tank is hydrogen fuel supply which obtained byReforming process of natural gas which is then delivered as liquid hydrogen from trailer to filling stationAnother method is delivering it from pipeline to filling station [9]. Hydrogen generated using electrolysers near filling stations. Hydrogen produced as by products from oil refineries [9]. TOTAL ENERGY USEThe energy delivered in vehicle tank is same amount as by other fuel types such as compressed natural gas and petroleum based which has less energy loss from well to tank but for methanol, hydrogen from natural gas, corn based ethanol has moderate energy loss from well to tank, the large well to tank loss occurs only with liquid hydrogen from natural gas, hydrogen electrolysis, bio ethanol cellulose [9]. CO2 GAS CONSIDERATIONSThe liquid hydrogen and compressed hydrogen gas from electrolysis are energy inefficient and they generate more amount of harmful gas, corn based ethanol has significantly reduced amount of green house gas [9]. The emission of co2 gas is very minimum when comparing to any other alternate systems since fuel cell technology mainly focuses on zero emission of vehicle [9].

TANK TO WHEEL ANALAYSIS

Comparing fuel cell technology to other conventional power train it uses less energy because of high efficiency of stacks. Mostly the hydrogen based fuel cell has more efficiency than onboard fuel processor [9]. FUEL CONSUMPTION OF CARMost of the fuel cell cars assumed to have solid polymer fuel cell (SPFC) but the energy requirement at the wheels is same as conventional engines. A starting point value of 0. 407MJ/km is used for everyday calculation which is obtained from a UK fleet where passenger car with gasoline fuel operation has fuel consumption of about 2. 7MJ/km which has the average efficiency of 15% is for gasoline car [1]. For other values Working backward from this value describes the energy requirementUnder new European driving condition the hydrogen obtained from natural gas is best suited for FCVs in terms of well to wheel analysis which also depends upon availability of natural gas [9]. C: UsersTOSHIBADesktopWell-to-Wheels-Vehicle-Efficiency-Comparison. png[credit: toyota motors]

PEMFC POWERED BUS

This is a better example for the fuel cell technology since this bus has been very successful till today which is being manufactured by Ballard power system which commercial partners like Chrysler, ford, this company manufactures for heavy and light duty vehicle application. They manufacture transit bus using solid polymer fuel cell for engine with 24 stacks with 5KW each for delivering 120KW [10].

FUEL CONSUMPTION OF BUSES

The requirement of energy at the wheels for fuel cell buses is similar to that of diesel buses. Based on general motor estimation conventional diesel engine has an efficiency of over drive cycle is 30% where as the total efficiency of drive train is 25. 5% from tank to wheel. The energy requirement is considered to be 3. 3MJ/km at the wheels using fuel consumption average of 13MJ/km. The hydrogen fuel for the fuel cell buses is transported through road to the bus depot. Then local steam reformer in the bus depot generates hydrogen through the natural gas which is used for the SPFC buses [10]. For new European drive condition for buses, have considerably increased for zero emission. The like van hool, rampini, Daimler, Wright bus, APTS with Ballard fuel cell system has involved in CHIC (clean hydrogen in European cities) [10]. For exampleInvolvement of Daimler in CHIC 2011 produced five Mercedes-Benz Citaro fuel cell buses for Canton Aargau in Switzerland. CHIC buses for London have been produced by Wright bus. APTS Netherlands produced buses for phileas in cologne [10].

CONCLUSION

The commercialisation of fuel cell automobile application in the market has entered its 5th year with development in reducing its production cost and strengthening its demand. From 2008 to 2012 there is a huge demand for fuel cell technology where shipments is listed below[credit: market analyst Jonathan wing]Therefore fuel cell vehicle is reaching its target for alternate fuel vehicle