Hydrogen Fuel Cell Vehicle

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Abstract- This paper discusses energetic, environmental issues and the role of hydrogen and fuel cell technologies as one of the potential solutions to these issues. The industrialized countries like USA, Canada, Japan have started commercialized plans for these technology by identifying the most likely early markets for hydrogen as an energy carrier and fuel cells as power producing devices from micro applications to macro applications. The paper also presents possible future of hydrogen energy for better environment and development, and also shows how the principles of thermodynamics can be used to evaluate hydrogen and fuel cell systems. Throughout the paper current and future perspective regarding thermodynamics and future development are consider.

Keywords – Environmental, Hydrogen, Fuel cell, Thermodynamics.

I. Introduction

Energy is the main element of interaction between nature and society. And is considered key input for environment and development In light duty vehicle sector there are exceedingly few economically viable substitutes to dominant energy source is gasoline. But due to this gasoline the global climate changes because of emission of carbon dioxide. And these emissions have motivated vigorous policy debate on alternative pathways for the light duty vehicles transportation sector.

The hybrid gasoline vehicles leave considerable opportunity for improving the fuel economy of light duty vehicle. However, several technologies hold promise for powering vehicle with lower carbon feedstock. In both cases hydrogen can be used as energy carriers, in which energy can be generated from variety of sources.

This paper shows how fuel cell vehicles use hydrogen gas to generate electric power so that with the help of this electric power motor run. Unlike conventional vehicles like truck, bus which runs on gasoline, fuel cell truck or bus combines hydrogen and oxygen which is used to generate electricity and to run motor. But the range of this fuel cell vehicle is comparable to conventional trucks and buses.

II. DESIGN AND OPERATION OF FUEL CELL

Hydrogen is an excellent fuel for fuel cell because it produces only water. Hydrogen containing fuels rich in hydrogen such as coal, biomass, ethanol methanol, methane and propane can also be used. Hydrogen is produced from this by means of a reforming reaction, carried out either externally or internally. In a fuel cell operated at high temperatures (e.g. molten carbonate fuel cell) the heat is used for generating H2 and CO2 as well as facilitating electrode reaction simultaneously.

In a low temperature fuel cell, the reforming process occurs in an external reformer and the hydrogen produced is consumed to generate electricity. Figure shows main components of fuel cell system.

If natural gas has to be used, it is processed in a reformer to create hydrogen rich fuel. Figure shows schematic diagram of H2 O2 fuel cell. The processed fuel is fed to the fuel cell between the end plate (or bipolar separator plate) and the nickel anode. Simultaneously, air (oxygen) is cleaned with filters and then channeled between the cathode and bipolar separator plate (or end plate). Sandwiched in between the anode and the cathode is the electrolyte (40% KOH). This porous material enables the hydrogen and oxygen to chemically react. Electrode reactions occur releasing free electrons that flow an external circuit, through load and to the cathode.

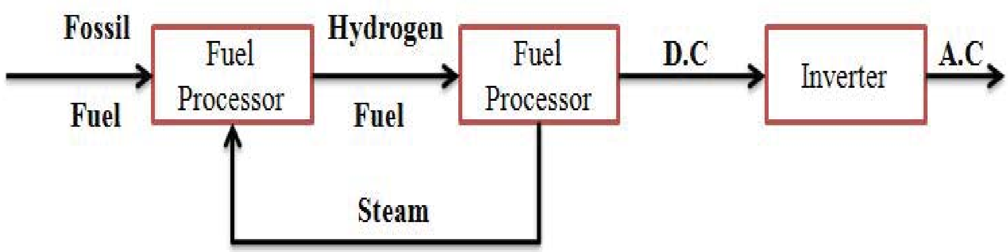

Figure 1. Operation of fuel cell

The following reactions takes place in fuel cell:-

Anode: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Overall cell reaction: $2H_2 + O_2 \rightarrow 2H_2O$

III. CLASSIFICATION OF FUEL CELL

Before describing the different types of fuel cells, it is necessary to have some method of classification of various types of fuel cell, which are either in existence or are being invented. Several methods of classification of fuel cells hand appeared in the literature. One of the difficulties in arriving at a systematic classification is that several operational variables exist. A broad classification is done according to whether the fuel cell system is primary or secondary one. A primary fuel cell may be defined as one in which the reactants are passed through the cell only once, the product of reaction being discarded e.g. H2/O2 fuel cell. In secondary fuel cell the reactant are passed through the cell many times because they are generated from the products by thermal, electrical, photochemical methods, e.g. Nitric oxide - chlorine fuel cell.

A) According to temperature range in which they operate:
- Low temperature 25 - 1000C.
- Medium temperature 100- 5000C.
- High temperature & very high temperature above 10000C.

B) According to physical state of fuel:
- Gas - Hydrogen, lower hydrocarbons.
- Liquid - Alcohol, hydrazine, higher hydrocarbon.
- Solid - Metals etc.

C) In terms of electrolyte used:
- Alkaline fuel cell.
- Phosphoric acid fuel cell.
- Molten carbonate fuel cell.

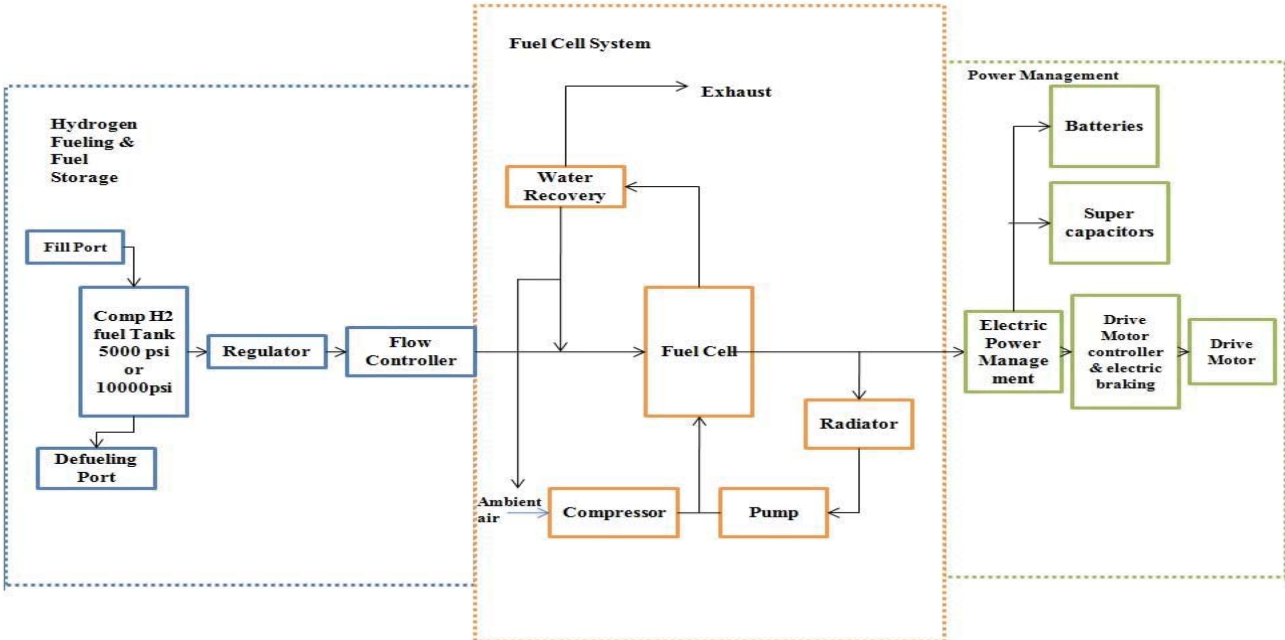

Figure 2. High level schematic of compressed hydrogen fuel cell vehicle sub system

IV. ELEMENTS OF COMPRESSED-HYDROGEN FUEL

Hydrogen fuel cell vehicles have an electric drive train powered by a fuel cell that generates electricity electrochemically from hydrogen. The major subsystem explained in figure is as below:

A) Hydrogen fueling and fuel storage subsystem;

B) Hydrogen fuel delivery subsystem;

C) Fuel cell subsystem; and

D) Electric propulsion and power management subsystem.

In addition to these primary subsystems, some FCVs are equipped with other advanced technologies to increase efficiency, such as the energy lost during braking and store it in an upsized battery. Following is a description of each of these subsystems and their typical location within a hydrogen vehicle drive train

The focus of this study is on the hydrogen fueling and fuel storage, hydrogen fuel delivery, and fuel cell and therefore does not address the electric propulsion and power management subsystem.

A) Hydrogen Fueling and Fuel Storage Subsystem

At present, the most common method of storing and delivering hydrogen fuel on board is in compressed gas form. Hydrogen is typically stored on current developmental vehicles at 5,000 psi (34.5 MPa). Compressed-hydrogen systems operating at 10,000 psi (70 MPa) are also in development. The hydrogen fuel from the storage containers is supplied to the fuel cell by pressure piping with two or three stages of regulation that reduce the pressure to approximately 5 psi (.034 MPa) before entering the fuel cell stack. For this report, fuel storage and delivery are discussed separately. The primary components within the hydrogen fueling and fuel storage subsystem are the compressed-hydrogen fuel containers. Because the hydrogen fuel has a low energy density per unit volume, storage containers must be designed to supply an adequate amount of hydrogen to achieve realistic vehicle driving ranges. Hydrogen fuel containers and fuel cell stacks also add weight and cost to the vehicle that compounds the challenge of achieving desirable driving ranges. To overcome these limitations, hydrogen fuel containers are being designed to take up as little space as possible using lightweight composite materials. In addition, these fuel containers are specially designed to allow the storage of hydrogen at very high pressures to overcome the low energy density.

B) Hydrogen Fuel Delivery Subsystem

Hydrogen is delivered from the storage containers to the fuel cell stack via a series of piping, pressure regulators, filters and flow meters. The fundamental purpose of a hydrogen flow control system is to easily deliver fuel to the fuel cell stack at a specified, stable pressure and temperature for actual fuel cell operation over the full range of vehicle operating conditions. Fuel must be delivered at a specified rate, even as the pressure in the fuel containers drop or the ambient temperature changes. The fuel system delivery specifications are determined by the initial container storage pressure, the vehicle, and the vehicle duty cycle. Since sections of the piping system will see container pressures of up to 10,000 psig (70 MPa) standards intend to ensure they are designed and tested to maintain this pressure safely without leakage or rupture throughout their service life.

C) Fuel Cell Subsystem

The fuel cell provides the electricity needed to operate the drive motors and charge vehicle batteries and capacitors. There are several kinds of fuel cells available in market, but Polymer Electrolyte Membrane (PEM) also known as Proton Exchange Membranes - fuel cells are the type typically used in automobiles at this time. The PEM fuel cell consists of a stack of hundreds of cells in which hydrogen and oxygen combine electrochemically to generate electrical power. Fuel cells are capable of continuous electrical generation when supplied with pure hydrogen and oxygen, simultaneously generating electricity and water, with no carbon dioxide or other harmful emissions typical of gasoline-powered internal combustion engines.

D) Electric Propulsion and Power Management Subsystem

Hydrogen fuel cell vehicles are powered by electric motors in which the electrical energy provided by the fuel cell is converted to the mechanical energy necessary to drive the wheels of the vehicle. The electric drive system has similarities to electric vehicles. It may also use batteries and ultra-capacitors similar to those used in hybrid vehicles. Many hydrogen fuel cell vehicles are front-wheel drive, typically with the electric drive motor and drivetrain located in the engine compartment mounted transversely over the front axle. This pattern is consistent for small fuel cell automobiles that are similar in size to existing economy cars. Some larger SUV-type fuel cell vehicles are all-wheel drive with two electric motors, one each over the front and rear axle, while other designs use four compact motors, one at each wheel.

V. CARBON DIOXIDE EMISSIONS

Carbon dioxide emissions from hydrogen are determined by the fuel use and the type of hydrogen feedstock. An in-depth discussion of hydrogen feedstock's can be found in NRC (2004), and this paper uses the assumptions from the NRC analysis. The following ten types of hydrogen feedstock's are examined:

- Central station generation natural gas (CS-NG)
- Central station generation natural gas with carbon sequestration (CS-NG Seq)
- Central station generation coal (CS-Coal)
- Central station generation coal with sequestration (CS-Coal Seq)
- Distributed generation natural gas (Dist-NG)
- Mid-size generation biomass (MS-Bio)
- Mid-size generation biomass with sequestration (MS-Bio Seq)
- Distributed generation electrolysis (direct generation using electricity) (Dist-Elec)
- Distributed generation wind turbine-based electrolysis (Dist WT-Elec)

- Distributed generation solar photovoltaic-based electrolysis (Dist PV-Elec)

Each of these feedstock's has unique costs and carbon dioxide emissions, and NRC further divides each of these technologies into "current" (C) and "future" (F) versions of the technology.

VI. CONCLUSION

Fuel cells can promote energy diversity and a transition to renewable energy sources. Hydrogen the most abundant element on Earth can be directly used. Fuel cells can also utilize fuel containing hydrogen, including methanol, ethanol, natural gas and even gasoline or diesel fuel. Energy also could be supplied by biomass, wind, solar power or other renewable source. Fuel cells today are running on many different fuels, even gas from landfills and waste water treatment plants.

Fuel cells are also ideal candidates for a new trend of power generation, called distributed power generation. With such an arrangement, many small scale factories, hospitals, shopping malls, hotels, airport etc. can produce their own electricity. There seems to be a good future for consumer ready fuel cell vehicles. Ford and Toyota are among those working on fuel cell vehicles. General Motors claims to have unveiled a fuel cell powered Opal car and developed nearly zero emission minivan that converts methanol into the gas for use in the fuel cell. Since the fuel cell relies chemistry and not combustion, emission from this type of a system would still be much smaller than emission from the cleanest fuel combustion process.

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