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FUEL CELL VEHICLES

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ABSTRACT

World leaders declared in 2009 that CO2 emissions must be cut by at least 80% (from 1990 levels) by2050 in order for atmospheric CO2 to stabilise at 450 parts per million (ppm) and keep global warming below 2°C.This level of decarbonisation could require up to 95% decarbonisation of the road transport sector. The internal combustion engine (ICE) is not expected to improve more than 30% in efficiency during that timescale and the availability and compatibility of alternative biofuels is uncertain; as such it is unlikely that conventional vehicles can meet this target alone. There is an evident need for zero-emission solutions across the full range of car types, from small cars for local use to larger, high-mileage vehicles.

To achieve the zero emission transportation Fuel Cell Vehicle can be the solution.

A fuel cell vehicle is similar to a battery operated vehicle in that it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical energy into electrical energy and also, as a by-product of this process, into heat. However, a battery holds a closed store of energy within it and once this is depleted the battery must be discarded, or recharged by using an external supply of electricity to drive the electrochemical reaction in the reverse direction.

A fuel cell, on the other hand, can run indefinitely as long as it is supplied with a source of hydrogen fuel (hence the name) and is similar to an ICE in that it oxidises fuel to create energy; but rather than using combustion, a fuel cell oxidises hydrogen electrochemically in a very efficient way. During the reaction, hydrogen ions react with oxygen atoms to form water; in the process electrons are released and flow through an external circuit as an electric current. The only exhaust is water vapour.

INTRODUCTION

Energy required for all over the world for transportation and power generation. Present energy system involves above 80% of energy from conventional sources from burning of fuel. Convention sources are available for coming few years which having main drawback of pollution.

a) Today need for fuel is,
b) Cheap and readily available Safe.
c) High energy density
d) Have no harmful pollutants.

In the fuel cell chemical energy is converted in to electrical energy. That is used to drive the vehicle that responds just you would expect an internal-combustion engine to respond. Hydrogen, the most abundant element on earth, is rarely found in its pure form. Most fuel cell systems employ acomponent called reformer to extract hydrogen from hydrogen rich fossil fuel. The byproduct of this process is water vapor which not at all pollutes the environment.

Today's petroleum fuelled ICE vehicles are only 20 to 25 % efficient in converting the energy content of fuels into drive-wheel power. In comparison, the hydrogen fuel cell vehicle is nearly twice as efficient, so it will require just half the fuel energy. By adopting hydrogen as automotive fuel, the transportation industry could begin the transportation from near could begin total reliance on petroleum to a mix of fuel sources.

Now a day research on use of fuel cell is in progress, main field of research is for transportation, because fuel cell gives more efficiency, minimum maintenance cost and almost zero emission. HONDA, TOYOTA, HYUNDAI are on progress for development of fuel cell powered cars.

Fuel Cell Vehicle

Fuel cell vehicles are vehicle which uses fuel cells as power source. Fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and potentially useful heat as the only byproducts. Hydrogen-powered fuel cells are not only pollution-free, but they can also have more than two times the efficiency of traditional combustion technologies.

Principleof Fuel Cell:

A fuel cell by definition is an electrical cell, which unlike storage cells can be continuously fed with a fuel so that the electrical power output is sustained indefinitely. They convert hydrogen, or hydrogen-containing fuels, directly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water. The process is that of electrolysis in reverse.

Overall reaction:

$2H_2(gas) + O_2(gas) \rightarrow 2H_2O + \text{energy}$.

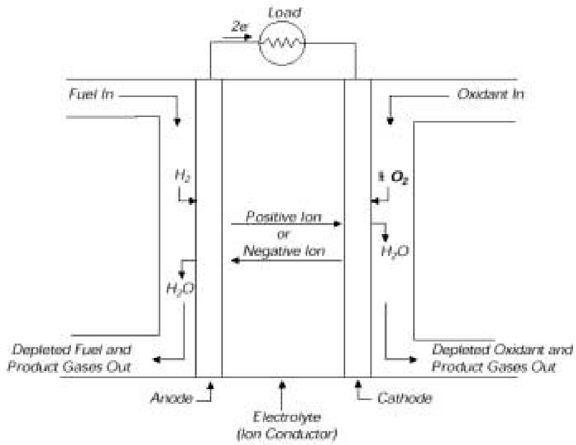

Fig. 1Schematic of an Individual Fuel Cell

All fuel cells consist of two electrodes (anode and cathode) and an electrolyte (usually retained in a matrix). They operate much like a battery except that the reactants (and products) are not stored, but continuously fed to the cell.

Fig. 1 shows the flows and reactions in a simple fuel cell. Unlike ordinary combustion, fuel (hydrogen-rich) and oxidant (typically air) are delivered to the fuel cell separately. The fuel and oxidant streams are separated by an electrode-electrolyte system. Fuel is fed to the anode (negative electrode) and an oxidant is fed to the cathode (positive electrode). Electrochemical oxidation and reduction reactions take place at the electrodes to produce electric current. The primary product of fuel cell reactions is water.

Workingof Fuel Cell:

A single fuel cell consists of an electrolyte sandwiched between two electrodes, an anode and a cathode. Bipolar plates on either side of the cell help distribute gases and serve as current collectors. In a Polymer Electrolyte Membrane (PEM) fuel cell, which is widely regarded as the most promising for light-duty transportation, hydrogen gas flows through channels to the anode, where a catalyst causes the hydrogen molecules to separate into protons and electrons.

The membrane allows only the protons to pass through it. While the protons are conducted through the membrane to the other side of the cell, the stream of negatively-charged electrons follows an external circuit to the cathode. This flow of electrons is electricity that can be used to do work, such as power a motor.

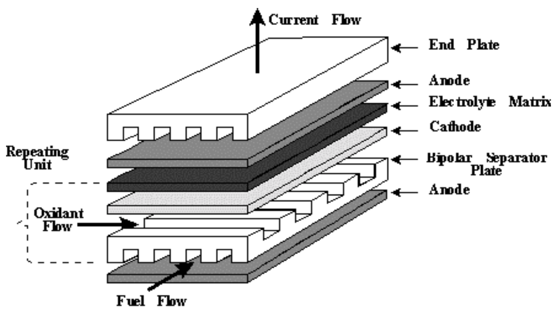

Fig. 2 Working Of Fuel Cell

On the other side of the cell, air flows through channels to the cathode. When the electrons return from doing work, they react with oxygen in the air and the hydrogen protons (which have moved through the membrane) at the cathode to form water. This union is an exothermic reaction, generating heat that can be used outside the fuel cell.

The power produced by a fuel cell depends on several factors, including the fuel cell type, size, temperature at which it operates, and pressure at which gases are supplied. A single fuel cell produces barely enough voltage for even the small-est applications.

To increase the voltage, individual fuel cells are combined in series to form a stack. (The term “fuel cell” is often used to refer to the entire stack, as well as to the individual cell.) Depending on the application, a fuel cell stack may contain only a few or as many as hundreds of individual cells layered together.

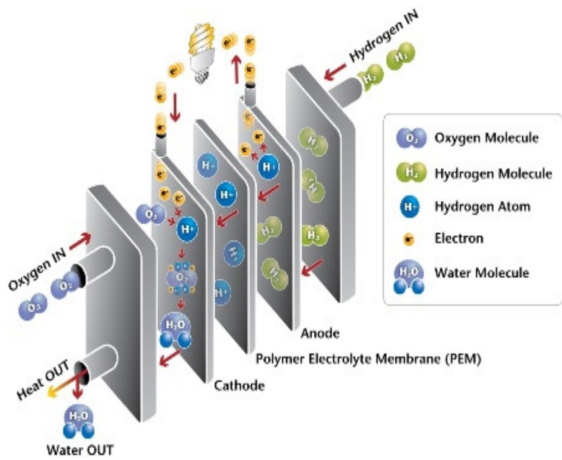

Fig. 3 Fuel Cell Sack

This “scalability” makes fuel cells ideal for a wide variety of applications, from laptop computers (20-50 W) to homes (1-5 kW), vehicles (50-125 kW), and central power generation (1- 200 MW or more).

Main Componentof Fuel Cell Vehicle

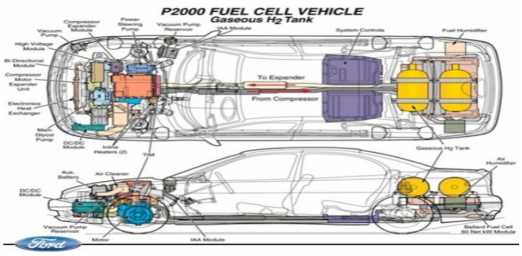

Fig. 4 Fuel Cell Vehicle

Here fig. 4 shows a fuel cell vehicle, where components of vehicle is shown. But in topic the source of fuel source vehicle is to be highlighted since other components are same as conventional vehicles. So we will only discuss the fuel cell system of the vehicle.

Basic components of fuel cell system are,

1. Gaseous H_2 Tank.
2. System Control.
3. Fuel cell.
4. Battery.
5. Electric Motor.

1. Gaseous H_2Tank

Fig. 5 Gaseous H_2 Tank

A hydrogen tank (other names- cartridge/canister) is used for H_2 storage. The first type IV H_2 tanks for compressed hydrogen at 700 bars were demonstrated in 2001, the first fuel cell vehicles on the road with type IV tanks are the Toyota FCHV, Mercedes-Benz F-Cell and the Hydro-Gen4.

Tanks are made of different materials like steel, aluminium, magnesium, fibre glass, carbon fibre. And tanks of different types are manufactured according to the pressure holding capacity; it varies from 175 bars to 700 bars,

The type IV H_2 tank which is used in fuel cell vehicle is made of composite material like carbon fibre with a polymer liner (thermoplastic). And approximate maximum pressure, plastic/carbon 661 bar and up.This H_2 tank is refilled at H_2 gas station with compressed H_2 gas at 200 to 350 bars. The tanks are fitted with a TN1 connector.The tank which is used are tested in accordance with ISO/TS 15869, which includes burst test, proof test, leak test and fatigue test.

2. System Control

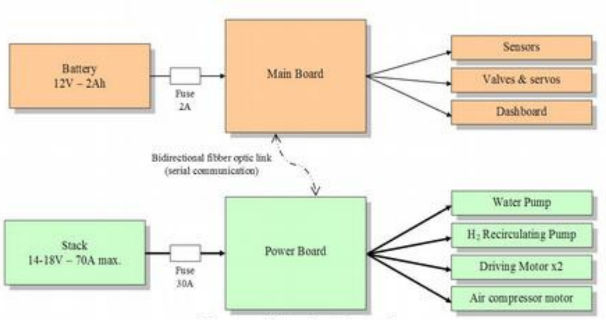

Fig. 6 Diagram of Electric Supply

System control is the main component of fuel cell system. It controls the whole electric supply of vehicle including the conversion of electricity produced by fuel cell stack in to AC to DC and vice-versa. It also manages the sensors and actuators, the other functions of it are shown in fig.

3. Fuel Cell

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent.Hydrogen is the most common fuel, but hydrocarbons such as natural gas and alcohols like methanol are sometimes used. Fuel cells are different from batteries in that they require a constant source of fuel and oxygen to run, but they can produce electricity continually for as long as these inputs are supplied.

Fig. 7 Fuel Cell

Welsh Physicist William Grove developed the first crude fuel cells in 1839. The first commercial use of fuel cells was in NASAspace programs to generate power for probes, satellites and space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are used to power fuel cell vehicles, including automobiles, buses, forklifts, airplanes, boats, motorcycles and submarines.

Currently, there are at least six different fuel cell types in varying stages of development. Four of these are receiving the most development attention. In general, electrolyte and operating temperature differentiates the various fuel cells. Listed in order of increasing operating temperature, the four fuel cell technologies currently being developed are:

- Proton exchange membrane fuel cell (PEM)—175°F (80°C)
- Phosphoric acid fuel cell (PAFC)—400°C (200°C)
- Molten carbonate fuel cell (MCFC)—1250°F (650°C)
- Solid oxide fuel cell (SOFC)—1800°F (1000°C)

From above, only three types of fuel cells are used in vehicles and there efficiency as compared to petrol engine (25-28%) and diesel engine (33-36%) is more, which can be advantage over them.

4. Battery

Battery is used to store the electricity produced by the fuel cell. So that the requirement of electricity can be manage. As mentioned earlier this management and distribution is done by the system control.

The battery used in fuel cell vehicle is Nickel-Metal Hydride Battery.A nickel–metal hydride Fig. 8 Battery in a Fuel Cell Vehiclebattery (NiMH)is a type of rechargeable battery. It is very similar to the nickel–cadmium cell.

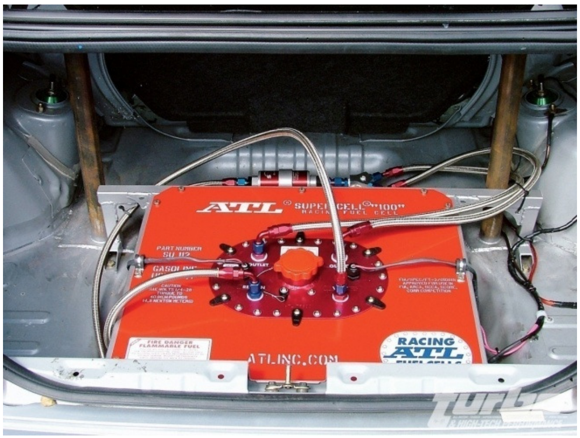

Fig. 8 Battery in a Fuel Cell Vehicle

NiMH use positive electrodes of nickel ox hydroxide, like the NiCd, but the negative electrodes use a hydrogen-absorbing alloy instead of cadmium, being in essence a practical application of nickel–hydrogen battery chemistry. A NiMH battery can have two to three times the capacity of an equivalent size NiCd and their energy density approaches that of a lithium-ion cell.

5. ElectricMotor

Fig. Electric Motor

An electric motor is an electro-mechanical device which converts electrical energy into mechanical energy. Most electric motors operate through the interaction of magnetic fields and current-carrying conductor to generate force.The physical principle behind production of mechanical force by the interactions of an electric current and a magnetic field, Faraday's law of induction, was discovered by Michael Faraday in 1831.

In fuel cell vehicle, electric motor propels the vehicle. And source is the electricity produced by fuel cells and then which is stored in batteries. The power produced by the motor is from 80 to 100 kW.

BENEFITS OF FUEL CELL VEHICLES

- Fuel cell vehicles are efficient. They have fuel cell which converts hydrogen and oxygen directly into electricity and water, with no combustion in the process. The resulting efficiency is between 50 and 60%, about double that of an internal combustion engine.
- Fuel cell vehicles are clean**.** If hydrogen is the fuel, there are no pollutant emissions from a fuel cell itself, only the production of pure water. In contrast to an internal combustion engine, a fuel cell produces no emissions of sulphur dioxide, which canlead to acid rain, nitrogen oxides which neither produce smog nor dust particulates.
- Fuel cell vehicles are quiet**.** A fuel cell itself has no moving parts, although a fuel cellsystem may have pumps and fans. As a result, electrical power is produced relatively silently.
- Fuel cells are environmentally safe.They produce no hazardous waste products, and their only by-product is water (or water and

carbon dioxide in the case of methanol cells).

- Fuel cells may give us the opportunity to provide the world with sustainable electrical power.

BENEFITS OF FUEL CELL VEHICLES

At present there are many uncertainties to the success of fuel cell vehicles and the development of a hydrogen economy:

- Fuel cell vehicles must obtain mass-market acceptance to succeed.This acceptance depends largely on price, reliability, longevity of fuel cells and the accessibility and cost of fuel. Compared to the price of present day alternatives e.g. diesel-engine and batteries, fuel cells are comparatively expensive. In order to be competitive, fuel cell vehicles need to be mass produced less expensive materials developed.
- An infrastructure for the mass-market availability of hydrogen, or methanol fuel initially, must also develop.At present there is no infrastructure in place for either ofthese fuels. As it is we must rely on the activities of the oil and gas companies tointroduce them. Unless motorists are able to obtain fuel conveniently and affordably,a mass market for motive applications will not develop.
- At present a large portion of the investment in fuel cells and hydrogen technology has come from automotive manufacturers.However, if fuel cells provesuitable for automobiles, new sources of investment for fuel cells and thehydrogen industry will be needed.
- Changes in government policy could also plans fuel cell vehicles development. At present stringent environmental laws and regulations,such as Euro Norms, Bharat stages have been a great encouragement to these fields.
- At present platinum is a key component to fuel cells which is key component of fuel cell vehicles**.** Platinum is a scarce natural resource; the largest supplies to the world platinum market are from South Africa, Russia and Canada. Therefore a new element or material should be discovered.

RECENT DEVELOPMENT

4.1 World:

At the beginning of 2002, the Bush Administration announced the Freedom-CAR initiative, an industry-government cooperative effort, to develop fuel cell vehicles. The motivation for the Freedom-Car initiative is to reduce U.S. dependence on imported petroleum, to reduce emissions of atmospheric pollutants, and to reduce CO2 emissions by improving fuel economy and/or by going to a hydrogen-based system. Since the transportation sector itself uses more oil than produced domestically, Freedom-CAR also addresses a serious national security issue.

The big three automotive manufacturers- General Motors, Daimler-Chrysler, Ford have publicly committed their companies to participation in the initiative.

In his January 2003 State of the UnionAddress, President Bush announced a new five-year research initiative on hydrogen fuel and fuel cells.Unveiled Hydrogen Fuel Initiative seeks to develop hydrogen, fuel cell & infrastructure technologies needed to make it practical & cost-effective for large numbers of Americans to choose to use fuel cell vehicles by 2020.

In his 2006 State of the Union address, he announced the U.S. government's hydrogen fuel initiative, which complements the President's existing Freedom-CAR initiative for safe and cheap hydrogen fuel cell vehicles.

And now recently there is tremendous development in fuel cell vehicle. Many big automotive companies- Honda, Hyundai-Kia have shown their interest in fuel cell vehicles.

Fig. 9 Honda FCX Clarity FCV

The recent fuel cell vehicle launched isHonda FCX Clarity Fuel Cell Vehicle. It is upgraded version of Honda FCX 2005.It consist PEMFC fuel cell stack, Li-ion Battery, High-pressure hydrogen tank, tank capacity- 171 L. Its maximum speed is 160 kmph and mileage is 90 kmpl.

4.2 India:

- Tata Motors has now developed a range ofhydrogen fuel cell-powered buses and lighttrucks. The fuel cell-powered commercialvehicles, developed at Tata Motors’ EuropeanTechnical Centre, are undergoing trial run.
- TATA and ISRO are partnering a fuel cell bus demonstration program in India.
- REVA electric Car Company has demonstratedfuel cell powered passenger car.
- Mahindra and Mahindra is working with ARCI to develop Fuel cell powered 3 wheelers.
- For hydrogen fuel. Reliance Industries has initiated some work in fuel cell development and is in negotiations with many foreign suppliers.

Fig. 10 DRDO-REVA FCV

- DRDO –REVA has developed a fuel cell vehicle.

CONCLUSION

From all of the project research, conclusion is that Fuel Cell Vehicles have advanced rapidly in the last few years. As the automotive companies and other researchers worldwide continue to focus on the remaining challenges of balancing durability, cost, and high-throughput manufacturability, it can be predicted that improvements will result in a manageable incremental cost for fuel cell technology and as well as fuel cell vehicles. Therefore it is expected continued progress to lead to several vehicle manufacturers introducing thousands of vehicles to the market by 2020, at which time the hydrogen community will have its first true test of whether the technology will be embraced by the public.

REFERENCES

Reports and Journals:

1) "Hydrogen Fuel Cell Vehicle Study" A Report Prepared for the Panel on Public Affairs (POPA), American Physical Society: June 12, 2006.
2) "Hydrogen Fuel Cell Automobiles" By Bernard J. Feldman, University of Missouri–St. Louis, St. Louis. Published in magazine-The Physics Teacher, November 2005.
3) "An Introduction to Fuel Cells and Hydrogen Technology" By Brian Cook, Director of Heliocentris, North America.
4) "Indian Fuel Cell Activity" By Centre for Fuel Cell technology, ARCI, India.
5) "Modelling and Control of Fuel Cell Systems and Fuel Processors" A Report by Jay TaweePukrushpan, Department of Mechanical Engineering. The University Of Michigan.
6) "Power train System of Honda FCX Clarity Fuel Cell Vehicle"ByHonda R&D Co. Ltd, Japan. Published in World Electric Vehicle Journal, 2010.

Internet Source:

1) www.ballard.com
2) www.internationalfuelcells.com
3) www.h2fc.com
4) www.eere.energy.gov/informationc enter
5) www.nrel.gov/hydrogen