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HYDROGEN POWERED FUEL CELL VEHICLES

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ABSTRACT

A hydrogen vehicle is a vehicle that uses hydrogen as its onboard fuel for motive power. Hydrogen is a secondary source of energy. It stores and carries energy produced from other resources (fossil fuels, water and biomass). By using pure hydrogen to power fuel cell vehicles, pollution can be reduced to a great extent. Hydrogen vehicles include hydrogen fueled space rockets, as well as automobiles and other transportation vehicles. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or by reacting hydrogen with oxygen in a fuel cell to run electric motors. Widespread use of hydrogen for fueling transportation is a key element of a proposed hydrogen economy. The objective of this paper is to review the world wide effort of making hydrogen powered fuel cell vehicle the future transportation system and which can put an end to oil crisis.

KEYWORDS: *Internal combustion engine, Fuel cell vehicle, Molten Carbonate fuel cells, Phosphoric Acid fuel cells, Proton Exchange Membrane, Solid Oxide fuel cells.*

1. INTRODUCTION

Hydrogen fuel cell cars are electric vehicles that use a hydrogen fuel cell for power. Fuel cells are of interest to the physics community (e. g., see the recent Physics Today article by Joan Ogden [1]) and physicists are actively involved in research areas for potential hydrogen storage, such as carbon nanotubes. This is one of the wonderful futures of automobile industry. Most of the automobile manufacturers are working on this project and today most of them have one or more hydrogen fuel cell cars in their lineup of prototypes. Although this technology could not grow as such as it should be, but engineers are working hard to make it easy. Almost all hydrogen vehicles built so far are a hydrogen proton exchange membrane fuel cell. Hydrogen fuel cell cars are considered to be zero emission vehicles it is because they have no emission like any other vehicles. Indeed it is zero emission fuel from its origin to wheel.

Most tough task with this technology is to store hydrogen gas into a special tank, as when hydrogen fuel is produced using renewable energy such as wind, solar energy, geothermal or hydroelectric by passing electrical current through water (H_2O) and splitting it into H_2 and O, the hydrogen is then compressed to 5000 psi to 10000 psi and eventually pumped into a specially constructed tank and then into fuel cell that turns motors and then wheel of the car. According to Ref. [2] Toyota is preparing a fuel cell hybrid vehicle, called FCHV-4, for production. Two vehicles have been delivered to the University of California for research purposes [3]. The Toyota vehicle uses compressed hydrogen gas, as does the Honda FCX, currently being tested in California.

Although it is best technology ever but hydrogen fuel cell cars are still a future cars, A huge hydrogen refueling infrastructure will need. When it will become available then hydrogen power vehicle will be most dominant over any other technology such as electric power vehicles, petroleum fuel dependence vehicles etc, and this technology will reduce global warming and dependence upon foreign fossil fuels.

Fig. 1 Animated view of hydrogen fuel car

2. TYPES OF FUEL CELLS

Alkali: fuel cells operate on compressed hydrogen and oxygen. They generally use a solution of potassium hydroxide (chemically, KOH) in water as their electrolyte. Efficiency is about 70 %.

Molten Carbonate: fuel cells (MCFC) use high-temperature compounds of salt (like sodium or magnesium) carbonates (chemically, CO_3) as the electrolyte (Fig. 2). Efficiency ranges from 60 to 80 %.

Phosphoric Acid: fuel cells (PAFC) use phosphoric acid as the electrolyte (Fig. 3). Efficiency ranges from 40 to 80 %.

Proton Exchange Membrane (PEM) fuel cells work with a polymer electrolyte in the form of a thin, permeable sheet. Efficiency is about 40 to 50 %.

Solid Oxide fuel cells (SOFC) use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O_2) as electrolyte (fig. 4). Efficiency is about 60 %.

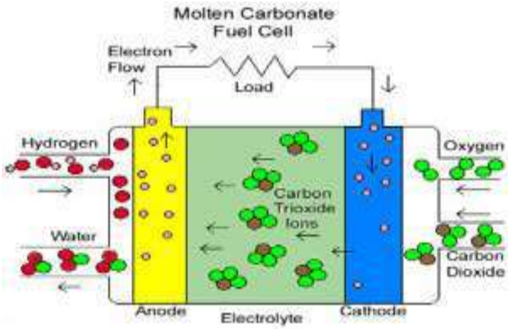

Fig. 2 Drawing of a molten carbonate cell

Automotive companies have been showing increasing numbers of fuel cell concept vehicles. At the same time, major automakers have announced plans to introduce production vehicles in the 2014, 2015 time frame. Quiet operation to generate electricity for stationary field applications is just as important to the military as higher fuel efficiency. The Army is presently letting contracts for Demonstration fuel cell powered trucks [4]. The impact that military funding might have for fuel cell development is huge. The reasons are simple. First, automakers are under pressure to build lower emission and emission-free vehicles and second, fuel cell vehicles don't have the severe range limitations that plague battery electric vehicles. Weiss et al. [5] made reasonable assumptions about the future evolution of internal combustion engines and hybrid-electric vehicles in addition to predicting the pace of development for fuel cell vehicles. Production ready fuel cells for automobiles are in their early days, and dramatic improvements in size, weight and cost are still ahead of us

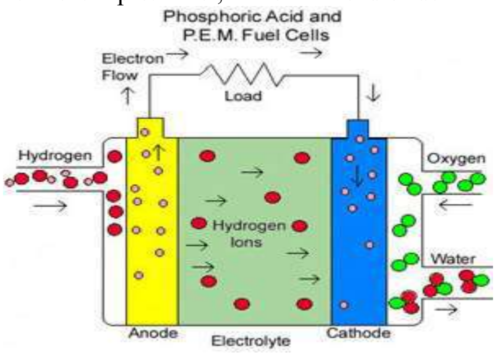

Fig. 3 Drawing of how both phosphoric acid and PEM fuel cells operate.

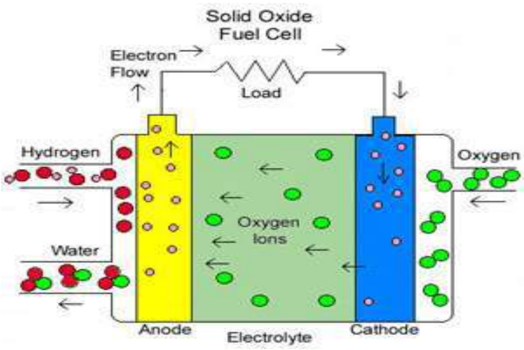

Fig. 4 Drawing of a solid oxide cell.

3. WORKING OF FUEL CELL

The fuel cell is composed of an anode, an electrolyte membrane in the center, and a cathode. Hydrogen flows into the fuel cell anode. Platinum coating on the anode helps to separate the gas into hydrogen ions and electrons. The electrolyte membrane allows only the protons to pass through the membrane to the cathode side of the fuel cell. The electrons cannot pass through this membrane and flow through an external circuit in the form of electric current.

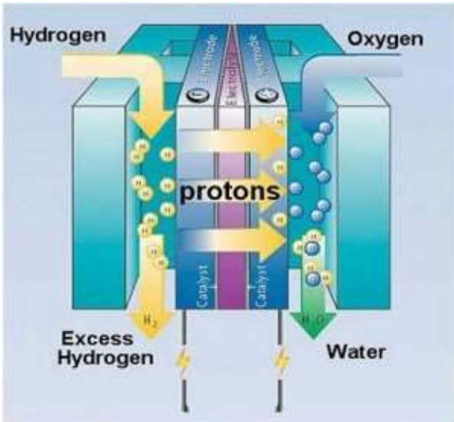

Fig. 5.Working of a fuel cell

The following steps explain the process of power generation in the fuel cell and their role in how does hydrogen powered cars work.

1. Hydrogen is pumped into the anode part of the fuel cell. Oxygen is usually taken in from the atmosphere by the positive cathode (Fig 6).
2. The negative anode, with the aid of the catalyst, splits the hydrogen cells and separates the electrons from it (Fig 7).
3. The electrons are then passed into a separate external circuit to form electric current, which propels the car forward (Fig 8).
4. Meanwhile, the hydrogen cells, which are devoid of electrons, as well as those electrons that went into the external circuits return to combine with oxygen (Fig 9).
5. The platinum catalyst facilitates the reaction between both the elements; as a result, water is formed. Water, besides some extra heat, is the byproduct of the reaction (Fig 10).

Since a single fuel cell produces only a small amount of energy, a number of fuel cells are put together for optimum power generation. This bundle of cells is called as a "fuel cell stack".

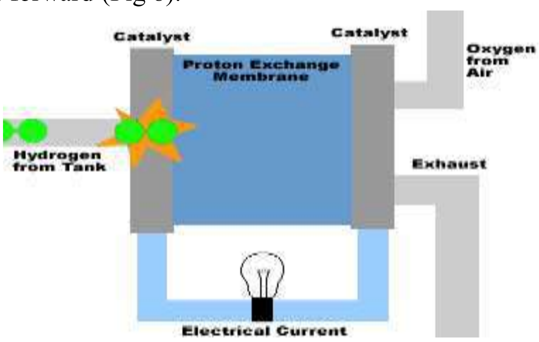

Fig.6. Event 1

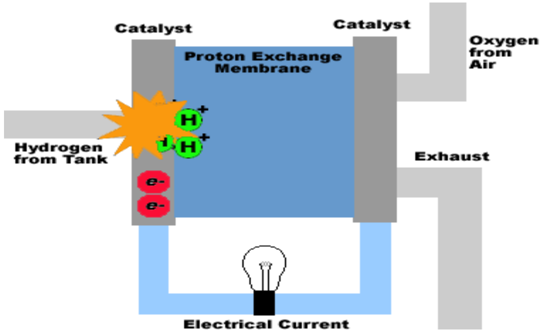

Fig.7. Event 2

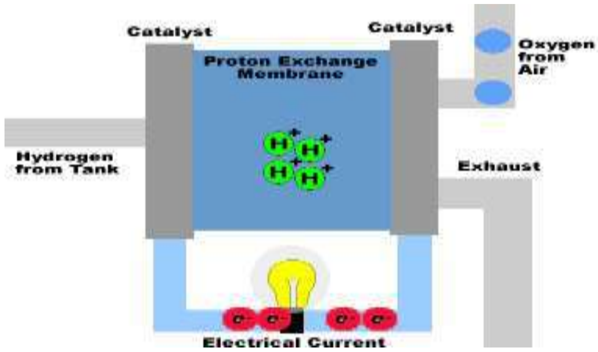

Fig. 8. Event 3

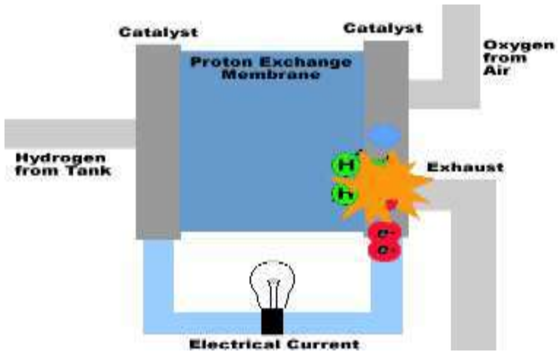

Fig.9. Event 4

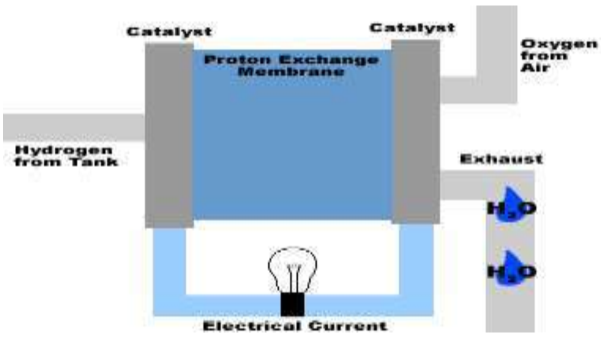

Fig. 10. Event 5

4. HYDROGEN PRODUCTION

Hydrogen is an energy carrier, not an energy source—hydrogen stores and delivers energy in a usable form, but it must be produced from hydrogen containing compounds. In the development of fuel cell vehicles, hydrogen storage is "the biggest remaining research problem" according to the January 2003 Office of Technology Policy report, Fuel Cell Vehicles: Race to a New Automotive Future [6].

Hydrogen can be produced using diverse, domestic resources including fossil fuels, such as coal (preferentially with carbon sequestration), natural gas, and biomass or using nuclear energy and renewable energy sources, such as wind, solar, geothermal, and hydroelectric power to split water. This great potential for diversity of supply is an important reason why hydrogen is such a promising energy carrier.

Hydrogen can be produced at large central plants, semi-centrally, or in small distributed units located at or very near the point of use, such as at refueling stations or stationary power sites.

Methods employed in hydrogen production:

- Natural Gas Reforming
- Renewable Electrolysis
- Gasification
- Renewable Liquid Reforming
- biological
- photo electrochemical
- Nuclear High-Temperature Electrolysis
- High-Temperature Thermochemical Water-Splitting

5. STORAGE

Developing safe, reliable, compact, and cost-effective hydrogen storage technologies is one of the most technically challenging barriers to the widespread use of hydrogen as a form of energy. To be competitive with conventional vehicles, hydrogen-powered cars must be able to travel more than 300 mi between fills. This is a challenging goal because hydrogen has physical characteristics that make it difficult to store in large quantities without taking up a significant amount of space.

Hydrogen storage will be required onboard vehicles and at hydrogen production sites, hydrogen refueling stations, and stationary power sites. Possible approaches to storing hydrogen include:

- Physical storage of compressed hydrogen gas in high pressure tanks (up to 700 bars).
- Physical storage of cryogenic hydrogen (cooled to -253°C, at pressures of 6-350 bar) in insulated tanks; and
- Storage in advanced materials — within the structure or on the surface of certain materials, as well as in the form of chemical compounds that undergo a chemical reaction to release hydrogen. The U.S. Department of Energy report, A National Vision for America is Transition to a Hydrogen Economy- to 2030 and beyond, projects that pressurized tanks will be the predominant hydrogen storage technology until about 2015, to be supplanted by hydride storage into the early 2020s, then other solid state storage technologies [7]. They see storage technologies maturing sufficiently for mass production in the 2020s. The Department of Energy timeline for development of storage systems projects that high pressure and cryogenic storage will be demonstrated in 2002-3, cost-effective hydride storage systems in 2003-6, and carbon-based storage systems in 2006-11 [8].
- Research into hydrogen storage technologies is still in its infancy, as reflected in the very low level of patenting in this area: 14 patents in 2001, and fewer in most previous recent years [9].
- Hydrogen storage faces deployment barriers that are
  • Fundamental (basic research still needed)
  • Developmental (engineering R&D required for practical designs)
  • Maturational (mass-production commitments premature)
  • Experience-limited (costs higher than long-run potential due to lack of production Experience)
  • Infrastructural (lack of appropriate fuel or service facilities)
- A review and research report published in 2002 considered hydrogen storage by graphite, graphite Nano fibers (GNFs), and single-walled carbon nanotubes [11]. Furthermore, "a liquid hydrogen storage system loses up to 1% a day by boiling and up to 30% during filling, as well as requiring insulation to keep the hydrogen at 20 K." [12].

6. LIMITATIONS

Widespread hydrogen implementation for vehicles has many obstacles to overcome. The cost of production, distribution and storage of hydrogen is still high, the cost of the cars is still high, and the availability of filling stations is just getting started. We are not trying to underplay the importance or difficulty overcoming these challenges. On the bright side, the potential advantages of fuel cells are so high, that the motivation to tackle the challenges is strong.

Fig. 11 Fueling station in Burlington,

Hydrogen has a very high energy content by weight (about three times more than gasoline), but it has a very low energy content by volume (liquid hydrogen is about four times less than gasoline). This makes hydrogen a challenge to store, Particularly within the size and weight constraints of a vehicle.

Aside from the loss of cargo space, there would also be the added weight of the tank(s), which could reduce fuel economy. Low-cost materials and components for hydrogen storage systems are needed, along with low-cost.

7. COMPARISION BETWEEN HYDROGEN FUELED VEHICLE AND OTHER VEHICLES

First you might ask how they are the same. An electric vehicle can get its electricity in one of three ways. Electricity can be transmitted to it as with some electrified roadways, subways, trams. It can have power stored on board in batteries, flywheels, or ultra-capacitors. And it can have the electric power manufactured on board. A series hybrid like a diesel electric locomotive has the diesel generator make electricity and then an electric motor runs the vehicle. The Volt is to a gasoline / electric series hybrid car. A purely solar electric car gets energy from the sun to run an electric motor. And last a hydrogen fuel cell car gets its energy from a hydrogen fuel cell to run an electric motor. So a hydrogen fuel cell car is a type of electric car.

But hydrogen is also a fuel that can be burned. Hydrogen could be used to power a steam engine car. And it has been used to power an internal combustion engine vehicle just like a gasoline car. Hydrogen is a fuel that has to be made. Usually it is from fossil fuels as this is the cheapest way to make it. About 5% is electrolyzed from water because it is energy expensive to make hydrogen it should be used in the most efficient way possible. A steam engine is least efficient. An ICE engine is only about 15% efficient by the time tires hit the road. But a fuel cell is about 50% efficient. A fuel cell is used to produce electricity and the electric car can be over 90% efficient. Therefore when you hear that a car is a "hydrogen car" you need to determine if it is a fuel cell electric car or a vehicle that uses an internal combustion engine that burns hydrogen as a fuel.

Hydrogen is a preferred fuel for vehicle for the following reasons.

- No carbon dioxide emissions, which are primarily responsible for atmospheric pollution.
- No more reliance on scarce and depleting fossil fuels.
- No more cold-weather trouble. Hydrogen-powered cars are compatible to cold weather.
- Hydrogen-powered cars are similar to normal cars. That they are huge in size is a 'huge' misconception.
- They are low on noise as well as vibrations.

CONCLUSION

Emissions produced from gas guzzling cars are one of the biggest environment killing factors in the world. Transportation is single-handedly responsible for 33% of the US greenhouse gas emissions and 66% of the oil used. A staggering figure, I'm sure you agree but there are people who are actively trying to do something about it.

There are a number of alternatives already being looked at. These include solar energy and wind farms but there are question marks over a great many of the possibilities. Biomass uses waste to produce gases that are in turn transformed into energy, but the use of pig waste has obvious environmental factors, namely the smell.

For a wind farm to be effective and produce anywhere near enough energy to prove useful, hundreds of large turbines need to be created; wherever there are plans to build them there are also complaints about the effect this has on the surrounding countryside. One option being used quite heavily at the moment is off shore wind farms, but even this idea has its protestors.

Nuclear is considered a dirty word, despite advancements in the world of nuclear fission. We are capable of building safe nuclear power stations, and nuclear power is probably the most efficient form of non-fossil fuel, but for now most of the world is opposed to its use.

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