Engineering Physics 4C3

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Technical Paper

Hydrogen Fuel Cell: The Development, Present Status and Conceivable Evolution of Alternative Automobile Engine

Abstracts:

Hydrogen fuel cell is the ideal replacement to traditional combustion engine. It can eliminate the production of CO2, SOX and NOX; has a higher efficiency, no engine noise. And it is 100% renewable.

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October 13, 2001

Section 1 Introduction

Green House effect had been one of the biggest environmental issues concerned by nations, and its caused is one of the many by-products from traditional Octane automotive combustion engine, Carbon Dioxide CO_2. Other by-products such as sulphur oxides (SOX) and Nitrogen Oxide (NOX) are also creating heavy environmental impact to the earth.

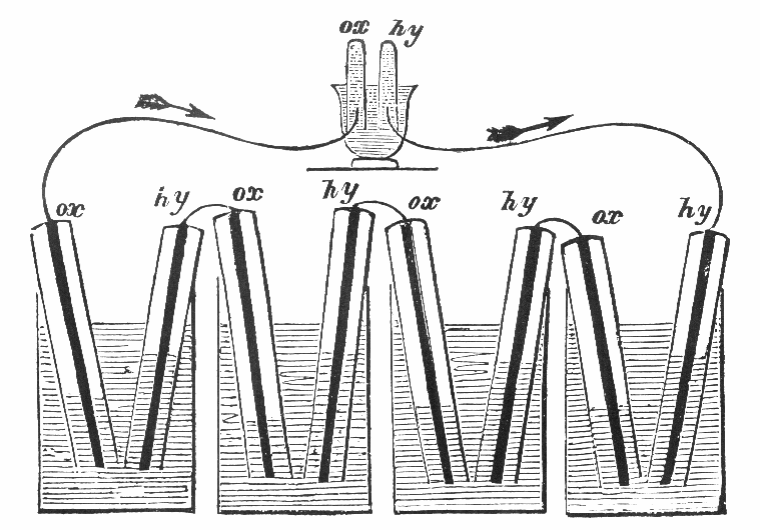
As a result, Scientists and Engineers are constantly seeking for solution on this issue. Some temporary solutions had been developed and using on the market already, these included using Natural gas, Alcohol, and Electric-Gas Hybrid vehicles. These different types of engine had eliminated the productions of SOX and NOX that created in the traditional engines. As well as partly reduced, the amount of Carbon dioxide produced in combustion.

However, amount of CO2 that produced are still too much for the nature to cycle. Therefore, an ultimate solution had been proposed. A solution that is safe, clean, efficient, and absolutely no CO2 will be produce. This solution is using hydrogen as the fuel, and using electrochemical process to generate electricity to power the vehicle. This is called Hydrogen Fuel Cell.

Section 2 History of Fuel Cell

History of Fuel Cell can be traced all the way back to 1839; Sir William Grove had first published his paper called “On Gaseous Voltaic Battery”

(Liebhafsky and Cairns, 18). The first "hydrogen fuel cell" was constructed by him in 1839, which the setup is as follow (Fig 2-1):



- *Fig 2-1: Four Cells of Grove's H_2/O_2 Battery to drive the electrolysis cell (Using H2 and O2 to electrolysis water) (Liebhafsky and Cairns, 20)*

In the above "cell", the Ox and Hy stand for the tubes fill with Oxygen and Hydrogen respectively, the dark line in the tube are "platinized platina foils" (Liebhafsky and Cairns, 19). In addition, the medium for the cells are dilute sulphuric acid.

50 years later, in 1889, L. Mond and C. Langer "reported the decline of reactivity of platinum black in electrolytes with time and extended the life of the cell by storing the electrolyte in a porous nonconducting material" (Breiter, 3)

After that, the fuel cell technology had been periodically under development. Different types of fuel cell prototypes were created. Some use carbon/air, some work with coal, etc. (Liebhafsky and Cairns, 19)

Section 3 Concept of Fuel Cell

A fuel cell is used to converts the chemical energy directly to electricity, which just like the regular batteries (Appleby and Foulkes, 3). Only different is, "in flashlight cell, the zinc negative-electrode structure is itself the fuel, and the manganese dioxide-carbon black positive-electrode structure is the oxidant." (Appleby and Foulkes, 3)

"A fuel cell consists of a fuel electrode (anode) and an oxidant electrode (cathode), separated by an ion-conducting electrolyte" (Appleby and Foulkes, 3). Then the load will be connected across the electrodes. (See fig 3-1)

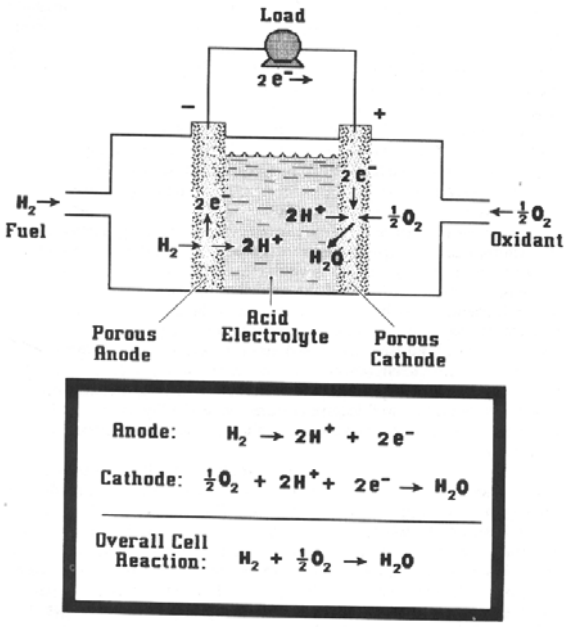


Figure 1–1: Principle of operation of a fuel cell.

• *Fig 3-1: Principle of fuel cell (Appleby and Foulkes, 5)*

As the above figure shown, Hydrogen fuel were being broke down to atoms, electrons were being captured by the anode and sent to the load. Hydrogen nucleus (protons) will "diffused" into the electrolyte. On the other side of the cell, oxygen was also being captured by the cathode, broken down to nucleus, and combined with the electrons from the load. Oxygen and Hydrogen ions combined and formed water.

Section 4 Current Researches

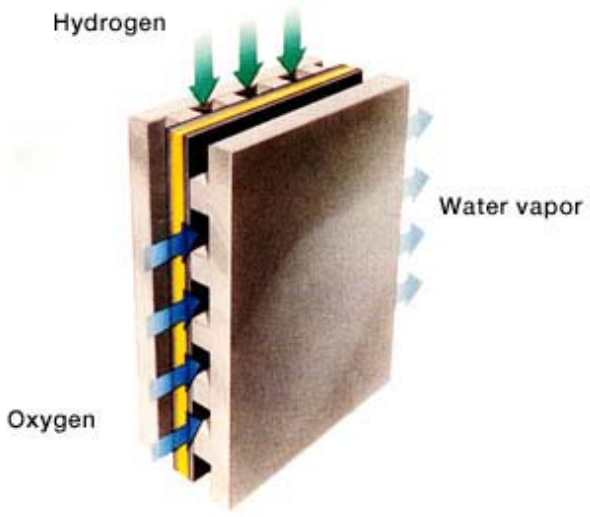
As the environmental damage done by conventional combustion engines increase daily, recognition of fuel cell engine from the industries is being developed. More and more automotive companies start their own research and development on fuel cell technology.

For example, OPEL and General Motor is a currently developing their own hydrogen fuel cell (fig 4-1). The new types of fuel cell are using solid electrolyte instead of liquid acid. The electrolyte being used is called Proton Exchange Membrane. Advantage of that is can work under lower temperature, as well as avoid leakage. Moreover, it will not affected by the motion of the vehicle.

- *Fig 4-1: fuel cell developed by General Motor and OPEL, stack of anode, cathode, and electrolyte layers packed within one fuel cell (HydroGen 1)*

Instead of just let the gases stay in a container like Grove did, they also had let the gases flow into the cell, in different direction. So that it can have a closer diffusing distance, and as a result, increase the reactivity (Fig. 4-2).

Moreover, instead of the water being produced in the electrolyte and dilute the concentration, water vapour is being produced in the oxygen side of the flow, then carried outside of the cell. This can greatly increase the efficiency of the electrolyte.



- *Fig 4-2: Illustration of a layer of the fuel cell stack, how the gases pass through and water being produce. (HydroGen 1)*

Currently, there are a few different methods are being used in order to store hydrogen fuel. For example, for the fuel cell developed by OPEL and General Motor, compressed liquid hydrogen was being used (HydroGen 1). And on the hand, Ford is using the fuel cell made by Ballard Power System (TH!NK), and in this case, methanol were being used (Ballard). In addition, other methods include Petroleum and Natural gas as hydrogen storages is in development as well.

For Compressed Liquid Hydrogen, it will provide a higher efficiency. Since the fuel does not require conversion to get hydrogen molecules. In the Hydrocarbon storage case, Hydrogen molecules have to be extracted in order to use in the fuel cell. This process required an extra step of electrolysis.

Section 5 Advantages of Fuel Cell

Aside from the absence of the green house gas and other gas by-products, there are still more advantages compare to traditional combustion engines.

In traditional combustion engine, fuel (octane) was being burned; heat is generated, thermo expansion occurred, and pushed the piston. The piston will provide power to turn the axial, and then transfer to the gears. During this process, enormous amount of power was loss in mechanical transition. On average, only about 20% of the energy had converted into power to move the vehicle (Ayres and McKenna, 66). The best diesel engine in the industry is about 35% efficiency (HydroGen 1).

However, for Hydrogen fuel cell, since there are no mechanical moving part in the energy conversion, electrons are directly brought to the motor in order to move the car, expected efficiency are about 60% (HydroGen 1).

In terms of noise pollutions, since Hydrogen fuel cell does not involve any mechanic, there will be virtually no noise except the “inaudible buzzing of the electric motor” (HydroGen 1).

In addition, since hydrogen can be generated from water by electrolysis, it will not have the limitation that gasoline had. Hydrogen is 100% renewable, as long as there is electricity. Moreover, electricity can be generated by solar, wind, or even nuclear power to avoid producing carbon dioxide.

Section 6 Futures of Fuel Cell

As one can see, hydrogen fuel cell certainly has its own potential to take over the traditional combustion engines one day. However, seems like there will be still a while before this day arrive, since there are quite a few problem waiting for engineers and scientists to resolve.

First, since fuel cell is operated with electro-chemical reactions, surrounding temperature played a very important role. The performance is highly depending on the temperature around, especially during the first few minutes it starts up. “Current fuel cell units can be started at -30°C, but need another minute to reach maximum performance” (OPEL).

Second problem is actually come from the by-product. Since the by-product is actually water, in winter temperature, water will turn to ice and expand. As a result, the expansion will break the stack and damage the cell. Solution proposed is developed a non-conducting anti-freeze to pass through the cell in winter (OPEL).

Other problem will be the fuel distributions. Currently, octane fuel already had a well developed distribution network. In order to use liquid compressed hydrogen, a new network must setup, since the current gas pump will not be able to handle the temperature and the pressure of the hydrogen.

Even though there are problem waiting to be resolved, the time hydrogen fuel cell become on the market will not be long.

Section 7 Conclusions

As one can see, Hydrogen fuel cells are ideal to replace the traditional combustion engines. It does not just resolved the problem of green house effects and air pollutions, but also provide higher efficiency, reduce the engine noise, and it is 100% renewable. However, this technology still requires some advancement before it used by publics.

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