Car Driven by Fuel Cell using Hydrogen Gas Generated by Chemical Reaction of Aluminium

H. Sanjaykumar[1] Sharankumar Patil[2]
[1,2]Department of Mechanical Engineering
[1,2]K G Reddy of Engineering & Technology, Ranga Reddy, Telangana, India

Abstract— With the rising prices of fuel, people are already looking at alternative modes of transport, electric cars being one. But what if you had a car that could run on water? This prototype draws power from water and aluminium and is claimed to have zero emissions. The process of running the car on water is based on simple fuel cell technology, which uses electrochemical reactions to produce electricity. The generated electricity is sent to an electric motor that fuels and drives the car. A fuel cell powered vehicle is conceptually simple. The fuel cell provides an efficient means of converting chemical energy to electricity. If a fuel cell with adequate power capacity could be housed within the engine compartment of a vehicle, its electrical output could be used to drive an electric motor for propulsion as well as all of the electrical ancillary equipment of a modern vehicle. This work concentrates much about turbines, their maintenance and various equipments installed to ensure the safe, reliable and efficient performance of the turbine. This deals with the controls of a turbine to regulate the speed to required and tripping devices and their working at emergencies. Fuel cell vehicles have a high potential to reduce both energy consumption and carbon dioxide emissions. However, due to the low density, hydrogen gas limits the amount of hydrogen stored on board. This restriction also prevents wide penetration of fuel cells. Hydrogen storage is the key technology towards the hydrogen society. Currently high-pressure tanks and liquid hydrogen tanks are used for road tests, but both technologies do not meet all the requirements of future fuel cell vehicles.
Keywords: Fuel cell, Prototype Car, Aluminium

I. Introduction

Automobile sector is one of the major sector in every country. With the increase in number of vehicles of road, the pollution is increasing rapidly and non-renewable energy sources are depleting. So research is being done to make use of renewable energy source in place of non-renewable energy source

A. About Fuel cell:

Our modern society is based on primary energy consumption. A direct link exists between energy consumption per inhabitant and the welfare of the populations in the different countries of the world. It is then of critical importance for any economy to understand its energy mix, (between fossil –coal, natural gas, oil, nuclear and renewable energy sources), its future strategic options and evolution pathways, together with the principle energy challenges it faces.

The European Union’s energy strategy, the EU 2020 strategy, aims to address energy security, resource efficiency and climate change challenges. The Union’s objectives by 2020 are: to reduce the greenhouse gas emissions levels by 20% to increase the share of renewable energies to 20% to increase the energy efficiency by 20%.

The need for developing appropriate technologies for harnessing renewable and/ or alternate sources of energy have gained significant importance globally, including in India, in view of increasing use of fossil fuels both for power generation and transportation with consequent environmental concerns on one hand and depleting reserves on the other. In this context, fuel cell technology, which can address these issues, is attracting a considerable attention.

B. Why Aluminium as Fuel:

A power system was developed that may provide the advantages of simple construction, silent operation, and high energy density. The energy system employs an aluminium-based fuel that is potentially safer, more reliable, and easier to refuel than alternatives. Additionally, an aluminium-fueled power system is simpler to start up and shut down than are gasoline engines, and the system operates in extreme environments such as beneath the sea.

The basic chemistry of aluminium as a fuel relies on a reaction with water to generate hydrogen and heat according to the following:

$$2Al + 6H2 \rightarrow 2Al(OH)3 + 3H2O + Q\ (Heat)$$

II. Literature Review

In 1939, British engineer Francis Thomas Bacon successfully developed a 5 kW stationary fuel cell. In 1955, W. Thomas Grubb, a chemist working for the General Electric Company (GE), further modified the original fuel cell design by using a sulphonated polystyrene ion-exchange membrane as the electrolyte. This became known as the "Grubb-Niedrach fuel cell". GE went on to develop this technology with NASA and McDonnell Aircraft, leading to its use during Project Gemini. This was the first commercial use of a fuel cell.

In 1959, a team led by Harry Ihrig built a 15 kW fuel cell tractor for Allis-Chalmers, which was demonstrated across the U.S. at state fairs. This system used potassium hydroxide as the electrolyte and compressed hydrogen and oxygen as the reactants. Later in 1959, Bacon and his colleagues demonstrated a practical five-kilowatt unit capable of powering a welding machine. In the 1960s, Pratt and Whitney licensed Bacon's U.S. patents for use in the U.S. space program to supply electricity and drinking water (hydrogen and oxygen being readily available from the spacecraft tanks). In 1991, the first hydrogen fuel cell automobile was developed by Roger Billings.

III. Experimental Setup

The prototype car uses Aluminium + H2 + Fuel Cell Right now there are several radio controlled (RC) hydrogen powered cars on the market. Three of them are the HCell 20, the H2Go and the H-Cell RC

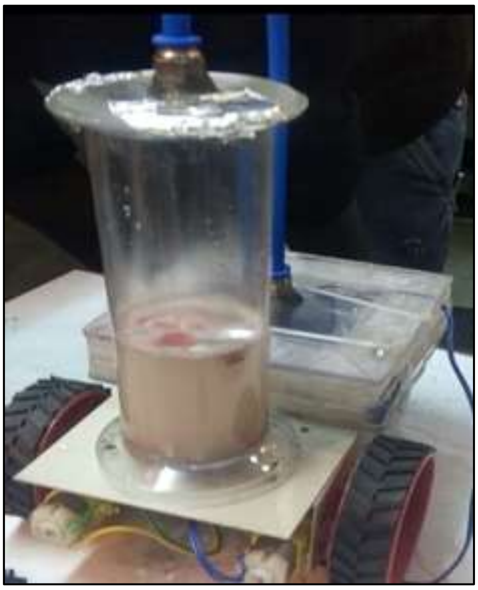

Fig. 1: Prototype Car

The car runs on pull tabs or any kind of waste aluminium plus Potassium hydroxide and water. Hydrogen is created and run through a tiny put powerful fuel cell that propels this beast 18.6 mph for 40minutes. Also notable is that the aluminium can be recycled along with the Potassium hydroxide. Now using aluminium to create hydrogen is nothing new.

A. *Aluminium*

Aluminium is a chemical element with symbol Al and atomic number 13. It is a silvery-white, soft, nonmagnetic and ductile metal in the boron group. By mass, aluminium makes up about 8% of the Earth's crust; it is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, though it is less common in the mantle below. The chief ore of aluminium is bauxite. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals.

Aluminium is remarkable for its low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and building industries, such as building facades and window frames. The oxides and sulfates are the most useful compounds of aluminium. Despite its prevalence in the environment, no known form of life uses aluminium salts metabolically, but aluminium is well tolerated by plants and animals. Because of these salts' abundance, the potential for a biological role for them is of continuing interest, and studies continue.

Aluminium's corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the bare metal is exposed to air, effectively preventing further oxidation, in a process termed passivation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

In highly acidic solutions, aluminium reacts with water to form hydrogen, and in highly alkaline ones to form aluminates—protective passivation under these conditions is negligible. Primarily because it is corroded by dissolved chlorides, such as common sodium chloride, household plumbing is never made from aluminium.

However, because of its general resistance to corrosion, aluminium is one of the few metals that retains silvery reflectance in finely powdered form, making it an important component of silver-coloured paints. Aluminium mirror finish has the highest reflectance of any metal in the 200–400 nm (UV) and the 3,000–10,000 nm (far IR) regions; in the 400–700 nm visible range it is slightly outperformed by tin and silver and in the 700–3000 nm (near IR) by silver, gold, and copper.

Aluminium is oxidized by water at temperatures below 280 °C to produce hydrogen, aluminium hydroxide and heat:

$$2\ Al + 6\ H_2O \rightarrow 2\ Al(OH)_3 + 3\ H_2$$

This conversion is of interest for the production of hydrogen. However, commercial application of this fact has challenges in circumventing the passivating oxide layer, which inhibits the reaction, and in storing the energy required to regenerate the aluminium metal.

IV. WORKING OF THE PROTOTYPE

The engine works like this: Potassium Hyrdroxide (KOH) is a very strong base – it’s incredibly caustic. It’s most commonly found commercially in an aqueous solution, meaning it’s mixed up with water. And what you feed that solution something like aluminium, a soft metal that strong bases love to chew up, the aluminium picks up the oxygen atom from the Potassium Hydroxide, which then in turn replaces the lost oxygen by stealing one from the water in its solution, the two free hydrogen atoms in gaseous form that bubble up and out of the mixture.

The process doesn’t start until you add the aluminium, and with time the aluminium eventually dissolves and the reaction stops (or until all of the lye and water in the solution have shed their Hydrogen atoms.) Until then, you get the benefit of hydrogen being released that you can use to power an engine. In the car, a couple of soda can tabs can get you a driving distance up to 72 miles.

Hydrogen + Oxygen = Electricity + Water Vapor

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

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

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

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (Proton Exchange Membrane) cell uses hydrogen gas (H_2) and oxygen gas (O_2) as fuel. The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-products. Since O_2 is readily available in the atmosphere, we only need to supply the fuel cell with H_2 which can come from an electrolysis process (see Alkaline electrolysis or PEM electrolysis).

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

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

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

V. Amount of Hydrogen Liberated

Hydrogen generation was carried out in a beaker, which capacity was 500 ml, containing 112gm of a potassium hydroxide aqueous solution from 0.1M to 5M. Aluminium foil was cut into little pieces. Each piece of aluminium foil was crumpled until forming a small ball, with a weight about 0.05-0.1g. In preliminary experiments 52g Al was added into the alkaline solution. The amount of hydrogen liberated is calculated.

$$2Al + 2KOH + 6H_2O \longrightarrow 2K[Al(OH)_4] + 3H_2$$

52gm 112gm 108gm 266.44gm 12gm

VI. Storage of Hydrogen

Compressed hydrogen in hydrogen tanks at 350 bar (5,000 psi) and 700 bar (10,000 psi) is used for hydrogen tank systems in vehicles, based on type IV carbon-composite technology. Hydrogen has a very low volumetric energy density at ambient conditions, equal to about one-third that of methane. Even when the fuel is stored as liquid hydrogen in a cryogenic tank or in a compressed hydrogen storage tank, the volumetric energy density (mega joules per liter) is small relative to that of gasoline. Hydrogen has three times higher specific energy by mass compared to gasoline (143 MJ/kg versus 46.9 MJ/kg). In 2011, scientists at Los Alamos National Laboratory and University of Alabama, working with the U.S. Department of Energy, found a single-stage method for recharging ammonia borane, a hydrogen storage compound. In 2018, researchers at CSIRO in Australia powered a Toyota Mirai and Hyundai Nexo with hydrogen separated from ammonia using a membrane technology. Ammonia is easier to transport safely in tankers than pure hydrogen.

VII. Conclusion

The only disadvantage of the proposed design was the cost. The hydrogen fuel cell and accessories for this system cost us about $155 which was expensive compare to battery operated system.

However, when we consider the fact that a hydrogen fuel cell has no green hour gas emissions and hydrogen fuel cell technology is still in the experimental stages, one can see that this technology has greater promise in the near future.

When fuel cell production becomes commercialized the cost of the fuel cell will go down.

References

[1] "Reduction of residential carbon dioxide emissions through the use of small cogeneration fuel cell systems – Commercial sector". IEA Greenhouse Gas R&D Programme (IEAGHG). 11 November 2008. Archived from the original on 5 March 2018. Retrieved 1 July 2013.

[2] "PureCell Model 400: Overview" Archived 14 May 2011 at the Wayback Machine. UTC Power. Accessed 2 August 2011.

[3] "Comparison of Fuel Cell Technologies" Archived 1 March 2013 at the Wayback Machine. Department of Energy,Energy Efficiency and Renewable Energy Fuel Cell Technologies Program. February 2011.

[4] AD. Hawkes, L. Exarchakos, D. Hart, MA. Leach, D. Haeseldonckx, L. Cosiins and W. D'haeseleer. EUSUSTEL work package 3: Fuelcells, 2006.

[5] "Reduction of residential carbon dioxide emissions through the use of small cogeneration fuel cell systems". IEA Greenhouse Gas R&D Programme (IEAGHG). 11 November 2008. Archived from the original on 4 May 2018. Retrieved 1 July2013.

[6] "HyER " Enfarm, enefield, eneware!". Archived from the original on 15 February 2016.

[7] "Global Hydrogen Fuel Cell Vehicle Sales Seeing Progress - HybridCars.com". HybridCars.com. 2018-02-09. etrieved 2018-03-26.

[8] "Hydrogen and Fuel Cell Vehicles Worldwide". TÜV SÜD Industrial Service GmbH, accessed on 2 August 2011