Section A-Research paper
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A Study of Feasibility of Hydrogen Vehicles

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Abstract
The air that we breathe in the cities today is highly polluted, causing grave risk to the health of the human beings staying in those cities. There are various causes of air pollution in the cities, the chief cause being vehicular smoke. In cities vehicles such as cars and buses are used which are fueled by petrol, diesel or CNG, which give out a large amount of smoke. This smoke contains many components which are harmful to the health of human beings. Recently electric vehicles have also entered the vehicular market. This paper discusses the feasibility of hydrogen vehicles.

Keywords—air pollution, petrol vehicles, electric vehicles, hydrogen vehicles.

I INTRODUCTION

People use vehicles for transportation. Most vehicles are powered by fossil fuels such as petrol, diesel or CNG. The fossil fuels are non-renewable, and will get finished within few years. Moreover, these vehicles give out smoke from their exhausts which is harmful to the health of human beings, animals and plants. To get rid of the problem of smoke, Governments all over the world are encouraging people to use the battery powered electric vehicles. An alternate fuel that has the potential to become the fuel of the future is hydrogen. This paper discusses the hydrogen fuel cell vehicles, which are a type of an electric vehicles, their pros and cons.

II WHAT IS HYDROGEN GAS?

The study of chemistry has uncovered more than 100 different elements, of which more than 90 are found in nature. Elements are inorganic compounds that cannot be decomposed into substances with fewer constituent parts and serve as the building blocks for all other types of matter. Hydrogen has the distinction of being the tiniest and least heavy of all the elements. It is 16 times lighter than oxygen. In contemporary chemistry, hydrogen is listed at the top of the periodic table as the first element. Under ambient conditions, atomic hydrogen (H) does not exit but as a molecule (H2) made of 2 atoms.

The combustible gas known as hydrogen was first found in the 18th century. Antoine Laurent de Lavoisier, a French scientist, is credited with being the first to use the term "hydro-gène" ("water producer") in 1787. The term is derived from the Greek terms "hydor" (water) and "genes" (creating). Henry Cavendish, an English scientist and physicist, was the first person to refer to it as "inflammable air" due to the fact that it had a high risk of catching fire. Every second, the sun burns about 4 million tons of hydrogen, which makes the sun shine. The German word "Wasserstoff" (which literally translates to "water substance") also relates to the water generating properties of the material. During the 19th and early 20th centuries, significant advances were made in the technology used to produce and make use of hydrogen. Even back then, its potential applications in the energy sector were recognized. The specific energy content, also known as the calorific or heating value, of hydrogen is quite high. Hydrogen has been given a significant part to play as a potential source of energy in a number of modern speculations about the future.

In 1874, Jules Verne is his book “The Mysterious Island” wrote: “Water will be the fuel of the future”.

Space travel, which significantly relied on hydrogen as an energy store, gave hydrogen a new drive in the 1960s. As a consequence of the energy and oil price crises in the 1970s, when the hunt began for alternative energy concepts, hydrogen was also given a new impetus at that time. During the 1990s, the cost of energy was relatively low, and as a result, interest in alternative types of energy was also low. Despite this, policies regarding the provision of energy began to be impacted more and more by concerns regarding sustainability, climate protection, and environmental protection. This resulted in a renewed interest in hydrogen as an alternative source of energy that is both clean and sustainable.

Since the density of hydrogen is very low, it is stored under pressure. Hydrogen gas liquefies at minus 253 degrees centigrade, which increases its density by 800 times. Since it is highly flammable, it has to be handled with care.

III WORKING OF HYDROGEN VEHICLE

What exactly is a hydrogen vehicle?

A vehicle that is powered by hydrogen fuel is referred to as a "hydrogen vehicle". There are two methods for utilizing hydrogen in motor vehicles: The first method involves using hydrogen in an internal combustion (IC) engine, which is similar to a petrol or diesel engine. When petrol or diesel is consumed in the Internal Combustion engine, the by-product is smoke which consists of carbon dioxide, carbon mono-oxide, nitrogen dioxide etc. but when hydrogen is burned the by-product is water vapour. Mazda has made a bi-fuel sports car called Mazda RX-8 Hydrogen RE, which can run on both: petrol or hydrogen. However, the method of using hydrogen in an IC engine is very challenging. The alternative method, which is also the most widely used one, involves a unique tool called a fuel cell. Given that its traction is provided by an electric engine, the hydrogen fuel cell vehicle is a member of the vast family of electric vehicles. A relatively tiny, lightweight, and very expensive electrochemical device that generates energy onboard replaces the large, expensive grid-charged battery pack in a hydrogen fuel cell vehicle, which is analogous to an electrical vehicle. Because hydrogen fuel cells can store energy more densely, they often have a longer range between refueling stops and don't emit any toxic gases. When a lithium-ion battery is used to power an electric vehicle, electrical energy is simply stored in the battery after being charged on the power grid. The difference is in this area. The fuel cell within the hydrogen fuel cell vehicle uses hydrogen that is stored onboard to provide the electricity needed to power the powertrain in addition to the battery. The hydrogen-powered vehicle aspires to drive without emitting any emissions, just as the "conventional" electric vehicle.

Types of Hydrogen vehicles

The hydrogen vehicles can be rockets, trains, buses, forklifts, cars, scooters, autorickshaws, scooters and even bicycles. NASA launched the space shuttles in orbits using hydrogen. The high effective exhaust velocity of hydrogen rocket fuel is an advantage over UDMH/NTO or kerosene/LOX engines Boeing tested a tiny hydrogen fuel cell-powered aircraft with a crew on board in February 2008. Hydrogen planes without crew have also been tested. The first Coradia iLint trains powered by fuel cells entered operation in northern Germany in 2018. Hyundai manufactures hydrogen powered “Xcient” Fuel cell commercial trucks and has exported to Switzerland and Israel.

An industrial forklift truck driven by a hydrogen-fueled internal combustion engine, often known as a "HICE" forklift or "HICE lift truck," is used to lift and move items. On May 27, 2008, the Linde X39 Diesel-based first production HICE forklift truck was unveiled at a convention in Hannover. Using a compressor and direct injection, a 2.0 litre, 43 kW (58 hp) diesel internal combustion engine was modified to run on hydrogen. In the US, material handling employed more than 4,000 fuel cell forklifts in 2013. For the years 2014 to 2016, it was predicted that there would be 1 million fuel cell-powered forklifts sold worldwide. There are businesses operating fleets all over the world. By 2020, Pike Research predicted, forklifts driven by fuel cells will be the main source of demand for hydrogen fuel. Due to the fact that forklifts operate indoors where emissions must be controlled, the majority of businesses in Europe and the US instead employ electric forklifts. Forklifts driven by fuel cells have an advantage over those powered by batteries in that they can be refueled in about three minutes. Since their effectiveness is not

compromised by lower temperatures, they can be employed in refrigerated warehouses. The fuel cell units frequently have drop-in replacement capabilities.

As far as cars are considered, the Toyota Mirai and the Hyundai Nixo are the two hydrogen cars that are widely available in the market. Mr. Nitin Gadkari, Union Minister of Roads and Highways is an owner of a Toyota Mirai car. The hydrogen tank of the car can be filled in around five minutes and has a 500 km range. The running cost of his car is Rs 2 per kilometre. This car is a part of the pilot project.

In an effort to boost the market for hydrogen-powered vehicles, Toyota declared in 2015 that it would make all 5,680 of its patents—which it has been developing for more than 20 years—relating to hydrogen fuel cell vehicles and hydrogen fuel cell charging stations available without charge to its rivals. However, Daimler had stopped working on hydrogen cars by 2017, and the majority of the automakers who were also researching hydrogen cars had shifted their attention to battery electric cars. Till date about 56,000 hydrogen passenger vehicles have been sold. In India Bajaj Auto and Mahindra HyAlfa have created hydrogen auto rickshaw concept cars.

The Intelligent Energy ENV motorcycles are propelled by hydrogen fuel cells. Triton EV of USA has introduced a hydrogen scooter, with a refueling time of 4 minutes and a range of 175 km. TVS is planning a hydrogen scooter in India. French company Pragma Industries created a bicycle in 2017 that could go 100 kilometers on just one hydrogen cylinder. The "Alpha Bike" product from Pragma was enhanced in 2019 and now has a 150 km range of electrically assisted pedaling.

Various types of hydrogen

Unlike fossil fuels, Hydrogen does not exist in reservoirs. Further it does not exist by itself but as molecules where it is joined with other elements like oxygen, carbon, etc. Hydrogen is frequently found in molecules such as water, ammonia, methane, etc. Hydrogen must be in its purest form to be used as a vehicle fuel. This implies that in order to extract the hydrogen, we must disassemble the molecules. Hydrogen can be produced by a variety of chemical processes. Although hydrogen is an invisible gas, depending on the production method, multiple color codes are assigned to hydrogen. The first approach involves the utilization of steam and hydrocarbons such as methane, however it has the drawback of utilizing fossil fuels. Following chemical reaction shows how methane with steam forms hydrogen.

$CH4 + H2O \longrightarrow CO + 3\ H2$

$CH4 + 2H2O \longrightarrow CO2 + 4H2$

Thus, predominantly hydrogen gas is formed. The term "grey hydrogen" refers to this substance. Bio-methane can also be used, provided there is sufficient availability of it. The second way of producing hydrogen is from natural gas. This is the most common method with a share of approximately 70 % and it is called “Blue hydrogen”. The third method is most environmentally harmful since it uses brown coal to produce “brown or black hydrogen”. In case of production of hydrogen from coal, greenhouse gas emissions are more than twice compared to hydrogen produced from natural gas. The fourth technique involves splitting water molecules with Direct Current (DC) electricity, which is accomplished through electrolysis. The two electrodes are coated with noble-metal, separated by a liquid electrolyte. There are no dangerous gases released using this procedure. It is referred to as “green hydrogen” if the electricity utilized is clean electricity (produced from renewable sources like wind turbines, geothermal energy, solar energy etc.). Electrolysis is a very expensive method. Many technologies are being explored with the goal of providing prices and quantities that are competitive with natural gas-based hydrogen production.

Hydrogen can also be produced from biomass using micro-organisms for fermenting and it is called bio-chemical production, but this method is still in its nascency.

STORAGE AND TRANSPORTATION

A major advantage is that hydrogen can be stored for long durations. However, for storing hydrogen, the density has to be increased significantly by compression and/ or cooling. Since hydrogen liquifies at minus 253 degree centigrade, it requires a complex factory and extra cost. Similarly, the transporting vehicles (tankers) are also very special, made of insulated double walls with vacuum in between, and thus are expensive. Thus, the storage and

transportation costs of hydrogen are comparatively higher than petrol. Pipelines can also be used for transporting hydrogen but since they need huge initial capital investment, they made not be financially viable unless the quantities of hydrogen are huge.

THE HYDROGEN FUEL CELL

In 1838/39 the principle of Fuel cell was discovered. However, it did not become popular due to heat engines. Fuel cells function similarly to batteries, except they do not need to be recharged: they generate electricity and heat as long as fuel is available. The process in a Fuel Cell is the reverse of Electrolysis: Direct current is used in the process of electrolysis, which separates water into its component elements of oxygen and hydrogen. However, in a fuel cell, the process involves the recombination of oxygen and hydrogen to form water while simultaneously producing direct current. A fuel cell is made up of two electrodes, one negative (or anode) and one positive (or cathode), sandwiched by an electrolyte. It also has a catalyst (a chemical compound that accelerates a reaction without being consumed; after the process, it may be collected from the reaction mixture and remains chemically unchanged). The anode receives the fuel, namely hydrogen, while the cathode receives air. A catalyst at the anode of a hydrogen fuel cell splits hydrogen molecules into protons and electrons, which travel in opposite directions to the cathode. Electrons flow across an external circuit, causing electricity to flow. Protons move through the electrolyte to the cathode, where they combine with oxygen and electrons to form water and helium. The Fuel cells are very expensive to make, because the catalyst is platinum. Research is going on to find a substitute for platinum as a catalyst, and if it happens the prices will go down.

Service period

The service period of a hydrogen vehicle is equivalent to other vehicles.

Storage of hydrogen in vehicles

Similar to LPG gas cylinders in our houses and in CNG vehicles, hydrogen is stored under pressure in the vehicles.

Infrastructure required

Just like we have petrol pumps for filling petrol in our vehicles, similarly hydrogen stations are required for dispensing hydrogen. The transportation of hydrogen can be done in tankers or through dedicated pipelines.

IV CHALLENGES FOR HYDROGEN VEHICLES

The Challenges

i) The cost: New infrastructure will be required which includes manufacturing plants to make hydrogen, storage facilities and hydrogen stations. Further, the cost of Hydrogen fuel cell vehicles is also very high compared to petrol/ diesel vehicles. Thus, the initial capital cost for the buyer is very high. However as more and more people buy them the costs would drop. However, there is a chicken and egg problem: vehicle buyers would want the infrastructure first and infrastructure providers would want that people buy enough vehicles first.

ii) The technology is very new. More research and testing are required. Governments can help.

iii) Low availability of hydrogen in general and carbon neutral hydrogen in particular. Most hydrogen is produced from methane or other fossil fuels which defeats the purpose of reducing the dependence on fossil fuels. Hydrogen should be manufactured from water by electrolysis, using renewable energy but this technology to make “green hydrogen” is very expensive.

iv) Common people do not have much awareness about the advantages of hydrogen vehicles.

BENEFITS OF HYDROGEN VEHICLES

i. Zero harmful emission, only water vapour comes out
ii. Fast refueling compared to electric vehicles
iii. Plug-free compared to electric vehicles
iv. Long range

v. Instant torque
vi. Smooth to drive
vii. Quiet
viii. Consistent power
ix. Hydrogen Fuel cells are lighter than Batteries of Electric vehicles
x. Safer than petrol/ diesel vehicles as during an accident the hydrogen will escape and not catch fire unlike petrol/ diesel.
xi. Low maintenance

V CRITICISM OF HYDROGEN VEHICLES

Some critics have argued that the technical and economic hurdles to widespread usage of hydrogen in cars will take at least a few decades to overcome. Elon Musk has said that a hydrogen car is a foolish idea. Fuel cells are taking resources away from more practical alternatives in the meantime. In the meantime, resources are being diverted to fuel cells rather than other, more viable options. Who Killed the Electric Car? a documentary from 2006, U.S. argues that Hydrogen is "a lousy way to move cars." The Los Angeles Times wrote in 2009. "a hydrogen car is one of the least efficient, most expensive ways to cut greenhouse gases". The majority of hydrogen is created using steam methane reformation, which releases at least as much carbon per kilometer as some modern petrol automobiles, therefore hydrogen vehicles will emit more carbon than petrol vehicles over their lifespan, according to the Washington Post. "it would surely be easier simply to use this energy to charge the batteries of all-electric or plug-in hybrid vehicles," The Economist noted, if hydrogen could be created using renewable energy.
According to Volkswagen's Rudolf Krebs, "Hydrogen mobility only makes sense if you use green energy". According to a 2017 review published in Green Car Reports: The finest hydrogen fuel cell cars use "more than three times more electricity per kilometer than an electric car," compared to other powertrain technologies, they produce more greenhouse gas emissions. Despite the availability of hydrogen powered cars, Hydrogen as an automobile fuel does not help reduce transportation-related carbon emissions. Carbon dioxide is still released during the production of 95% of the hydrogen, and it takes energy to make hydrogen from water. Getting hydrogen to gas stations requires more energy and might cause greater carbon emissions. Approximately 8 times as much hydrogen is required to move a Fuel Cell Vehicle (FCV) a kilometre than it does to propel a Battery Electric Vehicle (BEV) over the same distance. In 2019, Honda Europe President Katsushi Inoue said, "Our focus is on hybrid and electric vehicles now. Maybe hydrogen fuel cell cars will come, but that's a technology for the next era."

VI CONCLUSION:

From the study, it is found that the currently hydrogen vehicles are financially not feasible, as they are very expensive compared to vehicles powered by other fuels. However, if the prices of petrol and other fossil fuels increase and further research is able to reduce the manufacturing costs of hydrogen and hydrogen fuel cells, the hydrogen vehicles could become successful commercially.

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